Annual Report

#3
1957

ANNUAL REPORT OF THE JAPAN SEA REGIONAL FISHERIES RESEARCH LABORATORY

NO. 3

P.43
97

水　産　庁

日本海区水産研究所研究年報

第 3 号

昭和32年8月

水産庁日本海区水産研究所
新潟市万代島
JAPAN SEA REGIONAL FISHERIES
RESEARCH LABOLATORY
NIIGATA, JAPAN
August 1957

目　　次

日本近海産“マクルラス卵”の分類学的所属について……（西　村　三　郎）…… 1

Vertical distribution of the floating eggs of *Maurolicus japonicus* ISHIKAWA, a gonostomatid fish, in the sea ……（Saburo NISHIMURA）……13

Studies of the Conditioned Reflex in the Lower Vertebrates IV. Dfferentiation in Gold-fish……（Hideomi TUGE）……23

Studies of the Conditioned Rflex in the Lower Vertebrates V. Respiratory Defensive Conditioned Reflex in Carp……（Hideomi TUGE）……35

Some Remarks in Estimating Natural mortalites in Population Dynamics of Fish Resources……（Ichiro YAMANAKA）……43

イカによるイワシ類の食害量……（伊　東　祐　方）……53

On some plankton animals occuring in spring off Wajima, Noto Peninsula, Japan Sea, with special referenc to their vertical distribution ……（Saburo NISHIMURA）……61

卵黄吸収完了時におけるマイワシ稚魚の体重の推定……（西　村　三　郎）……73

Some Considerations Regarding the Amount of Foods Daily Taken by an Early Postlarva of Sardine ……（Saburo NISHIMURA）……77

A Transformation of Brain Form following the Growth of *Chasmichthyus gulosus* (*GUICHENOT*) ……（Kiyoshi UCHIHASHI and Yoshinori OGAWA）……85

External Form of the brain in Japanese Salmonoid fishes and its ecological meaning ……（Kiyoshi UCHIHASHI, Hatsutaro SHIMAMURA and Osamu SANO）……97

ズワイガニ *Chionoecetes opilio* の腹及び脚長節の相対成長とその段階について……（伊藤勝千代）…… 117

ヤリイカ *Loligo bleekeri* KEFERSTEIN の交接行動……（浜部基次，清水虎雄）…… 131

1955年春季日本海北部海域における表層流について—とくにマイワシ卵稚仔の移流との関係—……（笠　原　昭　吾）…… 137

表層流調査に用いられる海流瓶と海流封筒の効果比較について……（笠　原　昭　吾）…… 155

エゾボラモドキ *Neptenea intersculpta* (SOWERLY) の毒性について……（平井正夫，神名孝一）…… 167

漁獲物の鮮度保持に関する研究（第6報）2～3の防腐剤の鮮度保持効果……（山本常治，野口栄三郎）…… 171

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日本近海産“マクルラス卵”の分類学的所属について

西　村　三　郎

What is the spawner of the so-called “Macrurus egg” from the adjacent waters to Japan?

Saburo NISHIMURA

The so-called “Macrurus egg” which is rather commonly sampled by plankton haulings in the neighboring waters of Japan has hitherto been dubiously related to a certain species of Macrouridae as its spawner. The present author has tried to connect this fish egg well known for its peculiar structure with the true spawner from both biological and oceanographical points of view, and obtained the conclusion that it might be spawned by *Maurolicus japonicus* ISHIKAWA, a gonostomatid fish and common inhabitant in the twilight zone of the ocean.

I　はしがき

プランクトン・ネットによつてしばしば採集される魚卵の一種に，これまでわが国の魚卵・稚魚研究者たちから，“マクルラス卵”という名称で呼ばれてきたものがある。この魚卵はいわゆる‘Zackenei’であつて，非常に特異な形態をしていることと，量的にも多数採集されるために，研究者にはよく知られている卵である。その名が示すとおり，これはマクルラス科 Macrouridae（トウジン科，ソコタラ科）に属するある種の魚が放出する卵であると考えられてきた。この卵をマクルラス科の魚卵であるとする見解は，わが国では神谷（1916）がはじめてのべたところであるが，この著者は自身でそれを確めた訳ではなく，EHRENBAUM（1905）の記載に従つたものであるらしい。この神谷の記載，あるいは EHRENBAUM の原記載は，そのまま，後の研究者に受け入れられて，たとえば，内田（1941），伊東他（1951）などはいずれも，この魚卵をソコタラ科，あるいはマクルラス科の魚のものとして取扱つている。

この魚卵は，“Zackenei”の名が示すように，多数の突起を有する卵被をかむつており（実は，六角形をした凹面が規則正しく配列したものである），一見，金平糖状にみえる。1954年5月23日富山湾口にて採集され，フオルマリン固定後20個月を経過したもの20個についての測定結果を第1表の最下段に示す。この測定結果は神谷（1916）の与えた千葉県舘山湾産のものについての測定結果（第1表第3段）とほゞ一致し，固定の影響を考慮すれば両者は同一種の魚卵と思われる。

筆者は，日本海において採集されるこの魚卵の生態について調査を進めているうちに，これをマクルラス科の魚卵であるとする従来の見解に疑いを抱くようになり，種々考察を重ねた結果，これはキウリエソ *Maurolicus japonicus* ISHIKAWA の卵であろうという結論に達した。

Table 1.

Comparison of the "Zackenei" or "Macrurus egg" reported by various authors. Figures show the measurements in mm. on the diameter of respective items.

Author	Egg envelope	Perivitelline space	Yolk	Oil globule	Remarks
RAFFAELE (1888)	1.62	1.00	—	0.27	Live Mediterranean Sea
EHRENBAUM(1905)	1.35–1.63	0.91–1.01	—	0.25	Live North Atlantic
KAMIYA (1916)	1.46–1.82	0.98–1.17	—	0.23–0.28	Live Tateyama Bay
SANZO (1931)	1.32–1.58	0.92–1.00	—	0.26–0.28	Live (?) Artificial fertilization Mediterranean Sea
Present author	1.29–1.44	0.87–0.96	0.60–0.75	0.23–0.27	Fixed Toyama Bay

その後，東海区水産研究所の服部茂昌氏の御好意によつて，

SANZO, L. (1931) :
Uova, larve e stadi giovanili di Teleostei. Clupeoidei ; Salmonoidei ; Stomiatoidei FAUNA E FLORA DEL GOLFO DI NAPOLI, 38 Monografia.

をみる機会を得たが，この報文中で，SANZO は，地中海産のキウリエソ *Maurolicus Pennanti* WALBAUM の人工授精を試み，それまで Macrouroid fish のものとされてきた地中海産の "Zackenei" は，じつは，この魚の卵であることを確めているのを知つた。SANZO の与えたこの受精卵の測定結果を第1表4段に示した。(なお，参考のために，RAFFAELE 及び EHRENBAUM の測定をも採録してある。)

これによれば，"マクルラス卵" について筆者の得た測定結果より少し大きいが，その形態はほとんどまつたく同一であつて，おそらく地中海産の "Zackenei" と日本近海産のそれとは同種か，あるいはごく近縁の魚の卵であると考えられる。他方，SANZO が地中海産 "Zackenei" の親魚であることを発見した *Maurolicus Pennanti* は，日本近海産のキウリエソすなわち *M. japonicus* とは同種 (JORDAN *et al.* 1913, 蒲原 1949, MORI 1952 など) か，あるいは同種ではないとしても非常に近縁なものと考えられるので (ISHIKAWA 1915)，この点からみても，日本近海産の "Zackenei"——すなわち "マクルラス卵" とよばれてきたもの——はキウリエソの卵であろうとする筆者の結論は一層確かとなつたわけであるが，筆者のこの結論は，SANZO とは独立に，まつたく別個の考察の結果得られたものであるので，以下において，それぞれ理由を挙げてそれを得るにいたつたゆえんをのべたいと思う。

本論に進むにあたり，この研究を行う上に多大の御援助を賜わつた東海区水産研究所の服部茂昌氏，山口大学の片山正夫氏及び日本海区水産研究所の加藤源治，伊東祐方，大内明，深滝弘，渡辺和春の諸氏に厚く御礼を申しあげる。

Ⅱ “マクルラス卵”はマクルラス科の魚卵ではない

まず，この，いわゆる“マクルラス卵”をマクルラス科魚類の卵であるとする見解の不当性についてのべよう。

1. この魚卵は日本海においてはかなり普通に採集される。採集海域は広範囲に及び，かつ採集期間もほとんど周年にわたつている。この点からみれば，日本海にはこの卵を放出する親魚が相当豊富に棲息している筈である。従来の見解に従つて，これをマクルラス科魚類の卵であるとすれば，当然，日本海にはマクルラス科魚類が相当棲息していなければならない。

ところが，現在までの知見によれば，日本海には本科の魚類は量的にも質的にも非常に少ないもののようである。調査が不完全だつたための誤謬ではあつたが，GILBERT & HUBBS (1916) は，日本海の深海魚相のひとつの特徴はマクルラス科を欠いていることであるとのべているほどであるし，また，片山正夫氏からの1955年2月14日及び同23日付の私信によれば，日本海産マクルラス科魚類は正式に記載されているのは *Coelorhynchus multispinulosus* KATAYAMA の1種のみであり，かつ本種は稀にしか採集されず，日本海にはマクルラス科魚類は少ないとのことである。また，本間 (1952) の新潟県魚類目録にはマクルラス科を欠いている。柳井 (1950) によれば，山陰沖には *Coelorhynchus parallelus* (GÜNTHER) が分布しており，普通程度に漁獲されるとのことであるが，松原 (1955, p. 1310) によれば，日本海では兵庫県津居山以北，若狭湾に *C. multispinulosus* KATAYAMA を産し，これがマクルラス科魚類中日本海の底曳漁船でとれる唯一の種類であるという。前記柳井の *C. parallelus* もこれと同一種であるらしい（松原，前掲書，p. 1313)。

いずれにしても，日本海，とくに北部日本海（能登半島以北）にはマクルラス科魚類は質的にも量的にも稀なようであつて，これではとうてい多量に採集される“マクルラス卵”の起源を説明することはできない。

従来の見解を不利にする事実がさらにもうひとつ知られている。それはやはり，この卵の分布に関することであるが，日本列島の太平洋側で“マクルラス卵”が採集されるのは，金華山以南であつて，以北では採集されない（服部茂昌氏 1955年6月23日付私信)。ところが，マクルラス科魚類は金華山以北の海域に多量に棲息していることが知られている。たとえば，東北海区水産研究所が釧路から小名浜にいたる海域において，深度 500～1,000m の水域一帯を調査した結果によれば，漁獲物組成中ではマクルラス科魚類がもつとも主要な地位を占めており，かつ，深度が増すにしたがつて，一層多量に獲れるようになり，800～900m 以深ではほとんどマクルラス科の単一群集となるということである（東北海区水研 1954)。

それで，はたして，いわゆる“マクルラス卵”がマクルラス科魚類の卵であるならば，金華山以北の海域でもこの“マクルラス卵”あるいはそれに類似する卵が多量に採集されてもよさそうであるが，じじつはまつたくこれに反するのである。

2. プランクトン・ネツトで比較的浅い層から採集された“マクルラス卵”群中には，発生開始後まだ間もないと思われる発育段階のものがしばしば見出される。たとえば，筆者によつて，1954年5月23日，富山湾口において深度 30～55m から採集された166個中，76個（46%）が Blastula 期，37個（22%）が Gastrula 期のものであつた。また，時と場所とにより，稚魚ネツトによる表面採集のサンプル中にも，この魚卵を見出すことが稀ではないが，こうして採集された卵群中には発生初期の段階にあるものが少なからず含まれている。次にその数例を示そう（第2表)。

Table 2.
Records of catch of "Macrurus egg" by surface towing.

Locality	Date	Numbers by developmental stages					
		I	II	III	IV	V	Unknown
Fukui st. 3	Oct. 11, '54	3	42	5	19	1	7
Fukui st. 5	Oct. 11, '54	0	0	30	33	16	3
Hyogo st. 3	Nov. 1, '55	0	2	0	0	0	0
Hyogo st. 5	Nov. 1, '55	0	3	0	0	1	0
Toyama st. 2	Nov. 7, '55	0	0	0	1	2	0
Toyama st. 6	Nov. 7, '55	0	1	1	0	2	0
Fukui st. 3	Nov. 12, '55	0	0	4	1	3	0
Shimane st. 40	Feb. 19, '56	0	2	3	3	0	0
Fukui st. 3	June 1, '56	0	7	0	0	0	1

Stage I ·····Pre-cleavage stage
Stage II ·····Morula stage
Stage III ·····Blastula stage
Stage IV ·····Gastrula stage
Stage V ·····Post-gastrula stage

このような事実は，この魚卵が比較的浅い層で親魚から放出されるものであることを暗示している。深層において放出され，それが上層へ急速に浮上，あるいは運搬されるのであるとも考えられないことはないが，しかし，海水との比重差による浮上の場合の速度と湧昇流によつて運搬される速度は，深層から中層にかけては，いずれも非常に小さいものであろうと推定されるので，卵割開始以前のごく短かい時間のうちに，あるいは Blastula 期なり Gastrula 期を経過するに要する比較的短かい時間のうちに表面あるいはその付近まで浮上してくることは一般に不可能であろう。さらにまた，最近の研究によれば，湧昇現象は海面下せいぜい 200～300m 以浅の層にしか起らないものであつて，深層の水は関係せず，単に浅層における海水の上下混合 (overturning) によるものであるというから（日高，1955, p. 179），このような見解は一層受け入れがたい。

ところで，マクルラス科魚類の棲息深度は一般に非常に深く (MURRAY & HJORT 1912, その他)，日本海産のそれについては報告がないので不明であるが，東北海区における調査の結果によると，季節によつて多少の変化はあるが，一般的にいつて，350m 以深であつて，深度を増すにつれて次第に多くなり，900m 付近からは非常に多量に採集される（東北海区水研，1952 及び 1954)。もちろん，東北海区と日本海区とでは海洋条件が異るので，この結果からただちに日本海区における棲息深度をうんぬんすることは危険であろうが，とにかく相当深いと考えて間違いないであろう。日本海の底曳漁船では，本科魚類は前述したように稀にしか捕獲されないところから，たとえ棲息していても，それは少くとも 200～300m 以深と推定される。この推定は日本海における水温鉛直分布の状態を東北海区におけるそれと比較してみても妥当であると考えられる。

ところで，MARSHALL (1955) によれば，マクルラス科の魚類はよく発達した air bladder を有しているとのことであるから，垂直移動は可能なわけであり，じつさい，中層トロールで採集さ

れたという記録はあるが，しかし，本来の棲所は大陸傾斜及び深海底の軟泥地帯であろうという。MURRAY & HJORT (1912) も同じことをのべており，本科は純然たる深海性の魚類であつて，中層で採集されたものは stray individual にしかすぎないとのべている。すなわち，マクルラス科魚類は，その可能性は有しているのかもしれないが，じつさいは，群集をなしての表層付近までの顕著な垂直移動は行わぬものらしい。*

さて，次のような思考実験を行つてみる。日本海で採集される“マクルラス卵”はマクルラス科魚類によつて放出されたものと仮定する。すると，その卵の発育段階のごく若いものが表層から多量に採集される事実から，日本海にはマクルラス科魚類が多数棲息しており，かつ，前述の理由によつてそれは表層付近まで浮上してきて放卵することが結論される。しかし，第1の結論は前節で論じたように事実と一致せず，また，第2の結論もすぐ上にのべたこと，及び，もし，産卵時刻に浅層に浮上してくるものならば，日本海において本科の魚類がもつとしばしば漁獲ないし採集されてもよい筈であるが，じじつはそうでないという点において受け入れがたい。したがつて，上の仮定は否定され，“マクルラス卵”はマクルラス科魚類の卵ではないという結論に達する。

3. この“マクルラス卵”と相伴つて1種の稚魚がプランクトン・ネツトでしばしば採集される。卵，稚魚（第5図）がそれぞれ単独に採集される場合はもちろん多いが，同じ地点で採集されたり，あるいは同一のサンプル中に見出される場合もかなり多い。

筆者は，この稚魚について，(a)“マクルラス卵”と相伴つて採集されること，とくに浮游深度もほぼ一致していて，卵が多く採集されるところではこの稚魚も採集される機会が多いこと，(b) 孵化直前の“マクルラス卵”内の embryo と孵化直後と思われるこの稚魚とは，胚体の大きさが連続すること，全体的に形態が一致していること，体表に色素をまつたく欠くこと，肛門がともに胚体の中央部からやや後方に位置していること，卵黄の亀裂状態と油球の数，形状が同一であることなどから，これは“マクルラス卵”から孵出した稚魚であろうと推定した。

ところで，この稚魚の形態は，次にのべるように，マクルラス科親魚の形態とは著しく異なるのである。

(a) 体長 3～6 mm の後期稚魚の筋節数は 14+17=31 である。これに対して，マクルラス科成魚のそれは不明であるが，脊椎骨数をもつて比較すれば，*Coelorhynchus japonicus* では 50～53 であつて（北水研，1954），両者の間には著しい開きがある。なお，神谷 (1916) の記載によれば，“マクルラス卵”から孵出直後の稚魚には筋節数 36～37 が数えられたとのことであるが，これと筆者の観察との間の差違はどんな理由で生じたものか不明である。しかし，それはともかくとして，神谷の 36～37 にしても *Coelorhynchus japonicus*——氏は“マクルラス卵”をこの魚の卵であろうとしている——の成魚の脊椎骨数とは著しく異なつている。

(b) 上記の後期稚魚にはすでに尾鰭の原基が出現しており，そして，それは明らかに Homocercal の形態を示している。ところで，衆知のように，マクルラス科成魚の尾鰭は Leptocercal である。

(c) この稚魚の眼ははなはだ特徴のある形態を示す。すなわち，眼胞は上下方向に長軸をもつ楕円体であつて前面を向き，レンズは眼胞から著しく前方にとびでている。このような眼の構造は，その真偽のほどは別として，EHRENBAUM (1905) 及び MURRAY & HJORT (1912) のあげて

* しかし，MURRAY & HJORT（前掲書）及び MARSHALL（前掲書）によれば，本科の魚類はその生活史の前半を比較的浅い海で過すという。前者は 50～150m 層から後期稚魚を採集している。これは，しかし，親魚が浅層に浮上して放卵したためなのか，あるいは孵化後稚魚が自分の游泳力で浅層へ移動してきたためであるのか明らかでない。

いるマクルラス科魚類のものとされている後期稚魚の図にみるそれとはまつたく異つており，またマクルラス科と同じく Anacanthini に属する他科の魚類，たとえば，*Gadus, Molva, Onos, Theragra* などの諸属の稚魚にも，EHRENBAUM（前掲書）や遊佐（1954）などによつて人工授精と飼育から確められたところによれば，このような構造は全然みられないのである。

ところで，この眼の構造からすぐ想起されるのは，LO BIANCO (1903) 及び VON HOLT & BYRNE (1906) によつて "Periscope larva" あるいは "Praescope larva" という名称でよばれた一群の稚魚のことである。これらの稚魚では，ある発育段階において，眼胞が前方を向いていたり，また，レンズが著しくとびでていたりする。そして，これらの稚魚には広義の Scopelidae (=Iniomi) に属するものが多い。たとえば，*Myctophum punctatus, Idiacanthus fasciola* などその著明なものである（TANING 1918, BEEBE 1934）。筆者の，いわゆる "マクルラス卵" はキウリエソの卵であろうという推定は——キウリエソも広義の Scopelidae に属する——ここからその最初の暗示を得たのであつた。

このように，稚魚の形態的特徴も，問題の魚卵をマクルラス科魚類の卵であるとする従来の見解に対して，否定的な資料を提供する。

以上，1. から 3. にわたつてのべてきたところから明らかなように，"マクルラス卵" の分類学的所属に関する従来の見解には種々の難点があつて，とうてい受け入れることはできないのである。

Ⅲ "マクルラス卵" がキウリエソの卵であると考えられる根拠

前節でのべたように，いわゆる "マクルラス卵" はキウリエソの卵であろうとする筆者の推定は，この卵から孵出したものであろうと考えられる稚魚についての観察の結果から生起した。すなわち，まず，眼の構造にはじまり，さらにこの稚魚の筋節数とキウリエソ成魚の脊椎骨数との比較，その他，以下にのべるような諸事実によつてうらずけられた。

1. まず，キウリエソの分布状況であるが，本種が日本海に大量に棲息していることは，次の諸報告から知ることができる。すなわち，加藤（1954, 1955）は，日本海で漁獲されるスケトウタラの胃内容物中，魚類の大部分をキウリエソが占めていることを指摘しており，また，この他，マダラ，ホツケ，ハタハタ及び種々のカレイ類も本種を多量に摂取している（大内明氏談）。日本海中央部の大和堆で漁獲された種々の底魚類の胃内にも本種が見出された（田畑嘉六氏談）。戸井田（1915）及び筆者の観察によれば，キウリエソはスルメイカによつても多量に摂取されている。佐々木（1933）の調査によれば，ホタルイカも本種を餌料としてとつているらしい。* また，後にものべるが，サバのような回游性魚類も本種を摂取することが知られている（第4図）。

キウリエソは漁業生物学的にみて有用魚種ではないので，これを目的とする漁業は存在しないが，石川（1915）の記録によると，以前は，富山湾においては，他の有用魚種に伴つてもつとも多量に混獲される種類のひとつであつた。しかし，現在は，このように多量に混獲されることはないようである。これはおそらく網目の大きさが問題なのであつて，現在使用されている底曳網の網目は粗

＊佐々木は，キウリエソという名前は挙げてないが，ホタルイカの胃内に見出されたという "黒色あるいは銀色を呈せる動物の形骸"，"之を検鏡せば，魚類の皮膚にある閃光体の如きもの"，"閃光体様の物質及び魚類の脊椎骨と頭骨の一部を発見す" などという記述からおして，また，富山湾ではキウリエソがホタルイカと混じて定置網に入ることを考慮に入れると，この餌料魚類はキウリエソであると判断される。なお，問題の "マクルラス卵" はホタルイカの卵と伴つて採集される場合が多いという事実と考えあわせると興味深い。

らすぎてキウリエソのような小型魚類はぬけ落ちてしまうためであろうと考えられるが，稀にひつかかつてくることもあるという。また，富山湾魚津附近では，現在でも，毎年春季に，ホタルイカ捕獲を目的として沿岸に設置された小型定置網にキウリエソが，相当量混入することがあるという（第4図）。

以上のべてきたところからみると，直接の漁獲こそ多くないが，キウリエソは日本海には非常に多量に棲息しているであろうと推定されるのである。

さらに，この魚卵の日本列島をめぐる海域における分布をみると，太平洋側では金華山から鹿児島県まで，日本海側では青森県から長崎県に及んでいる。東北海区と北海道海区には分布しない（服部氏私信 1955，日本海区水研 1955，長崎水試 1955，北海道区水研 1955）。

他方，キウリエソ成魚の分布をみると，調査が不完全で正確な概念は得られがたいが，黒田（1951）によれば，相模湾，駿河湾，熊野灘，紀伊，四国，富山湾が挙げられているが，なお，このほかに，新潟県（本間 1952，加藤 1954 及び 1955），石川県，秋田県，兵庫県香住，島根県も付加さるべきである（加藤 1955）。朝鮮東北沿岸にも分布する（MORI 1955）。これから，青森県の西海岸は不明であるが，秋田県以南の日本海沿岸にはほぼ連続的にキウリエソが分布しているものと思われる。東北海区には分布をみない（笠原康平氏 1955年6月17日付私信）。北海道海区にも分布しないようである（飯塚篤氏 1955年6月30日付私信）。

すなわち，キウリエソの分布区域は，いわゆる“マクルラス卵”のそれとだいたい一致していることがわかる。

2. 日本海におけるキウリエソの棲息水深については，石川（1915）が，富山湾では 200—300 fathoms（m？）の深さから漁獲されるとのべているだけである。前述のように，現在は，本種は直接には漁獲されることがないので，このような方法による棲息水深の推定は不可能であるが，ただ，本種は中層ないし底層魚類の胃内容物として多量に見出されるので，それら魚類の胃内からの出現頻度を通じて，その棲息水深を推定することができるのである。ただし，この場合には，これらキウリエソ捕食魚類の摂餌時刻（もし，それがあるとすれば）及び摂餌に伴う行動，とくに垂直移動が問題になるが，スケトウタラに関しては，新潟県近海では，もつとも多く漁獲される体長 30～40cm のものは，少くとも白昼の 10～15 時ごろに摂餌活動が一度旺盛になるといわれており（日本海区水研 1953），※ また，スケトウタラは白昼に多く漁獲されるものであつて，かつ，この時刻に漁獲された魚体の胃内にはキウリエソが多数見出されること，及び，この時刻の前後には，スケトウタラは顕著な垂直移動は行つていないと考えられることから，キウリエソを胃内に有するスケトウタラが漁獲された水深をもつて，一応，キウリエソの昼間における棲息深度と見做して大きな誤りはないであろう。

詳細は後報にゆずり，ここでは得られた結果だけをのべると，日本海においては，キウリエソはだいたい 150～160m 以深に棲息しており，250～300m 附近にはとくに多いようである。棲息水深の下限については詳かでない。

ところで，蒲原（1949）によれば，本種は闇夜に海面近くへ現われて活潑に食を求めるという。夜間，まき網で漁獲された浮魚のサバの胃内にもキウリエソが見出されることがある（岡地伊佐雄

※同報告はさらに，夜中にも1回摂餌活動が旺盛になるらしいとのべている。元田・森山（1952）によれば，北海道近海のスケトウタラは午後おそくなつてから摂餌活動が旺盛になるという。また，三河（1956）は，東北海区においては，夕方になつてから索餌が多くなるようであるが，時刻の差はあまりみられないとしている。このようなくいちがいの一部は，各海区においてスケトウタラの餌料生物の種類がちがつていることに基くのであるかもしれない。

氏談)。これもキウリエソの夜間浮上を暗示するものであろう。すなわち，キウリエソはハダカイワシ類と同じく顕著な日週期的垂直移動を行う性質をもつているものであるらしい (MARSHALL, 1951 & 1955)。つまり，それは数多い Twilight fishes (TANING 1918) あるいは Lilliputians (MURRAY & HJORT 1912) のなかの一員であるらしい。それで，もし，夜間に浮上した時に，表層附近で産卵するものであると考えれば，* 前節の 2. においてのべた，早期発生段階にある卵が比較的浅い層で多数採集されたことの理由もおのづから解明されることになる。

表層性ないし中層性の海産魚類が夜間に産卵を行うという報告はかなり多い。たとえば，KUNTZ (1915) によれば，*Bairdiella chrysura* や *Anchovia mitchilli* は 18時から20時ごろまでの間に産卵する。伊東他 (1954) はマイワシは日没後浮上し 20～22 時にわたつて盛んに放卵するとのべている。ウルメイワシ，カタクチイワシもほぼ同様に 20～24 時ごろであろうと推定されている (中井他 1955)。マサバや *Scomber scombrus* も夜間に産卵するらしい (神谷 1925, BIGELOW & WELSH 1925)。

そして，この夜間産卵という現象は，夜間における魚類の一般的な活動の活潑化，具体的には浮上行動，と密接な関係を有するものであることは否定できないようである。そして，キウリエソの夜間における活潑な浮上行動が知られている以上，その浮上の際に産卵が行われると想像することは決して妥当性を欠いた推論とはいいきれないであろう。

このようにして，おそらく，キウリエソ卵は親魚が浮上した時に，比較的浅い層で放出され，多少の浮上あるいは沈降はするであろうが，暫時の後，前述したように，表面あるいはその付近から早期発育期の卵群として採集されたものと解釈されるのである。

3. スケトウタラ胃内から摘出されたキウリエソ成魚多数について，その脊椎骨数を調べたところによると，全部の標本が，Urostyle を含めて 33 であつた　この値は，いわゆる "マクルラス卵" から孵出したと推定される稚魚 (体長 3～6 mm) の筋節数 31 より 2 だけ多いが，この相違は，一方は脊椎骨数であり，他は筋節数であること，及び問題の稚魚はまだ発育途上にあることを考慮すると，当然ありうることと思われるのである。

さらに筆者は，1954年新潟県沖合で漁獲されたスケトウタラの胃内から得たキウリエソ成魚若干尾について調べたところ，そのなかにかなり成熟した卵巣卵を有する個体が見出された。卵黄径 0.7mm 以上の卵粒はすでに卵黄が透明になつており，直径 0.24～0.30mm の油球1個を有する。油球の大きさや色彩などは "マクルラス卵" のそれと一致する。これらの成熟した卵粒は卵被をかぶり，その卵被には，微弱ではあるが，明らかに Zacken 構造が認められる (第3図)。すなわち，キウリエソの成熟卵巣卵の構造は "マクルラス卵" のそれとよく一致しているのである。

Ⅳ あ と が き

以上，Ⅱから Ⅲ にわたつて，分布，生態，稚魚の形態及び卵巣卵などの検討から，日本近海において採集される，いわゆる "マクルラス卵" はマクルラスの卵ではなくて，じつはキウリエソの卵であろうと推定されるゆえんをのべた。

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* 太平洋海域では，夜間稚魚ネットの表面曳航を行うと，ハダカイワシが多量に入ることがあるが，日本海では，このようにしてキウリエソが採集されたことはまつたくない。とくに感覚が鋭敏で，かつ，稚魚ネットから逃れるほどの運動力を有しているのでないかぎり，これは，キウリエソは表面までは浮上してこないことを暗示している。表面下どの程度の深度まで浮上してくるのかは不明である。

もちろん，不備な資料に基いての推論であるから，断定するわけにはゆかないが，しかし，前述の諸理由から，それはかなり確かなものと思われる。この推定を実証するためには，キウリエソ成熟魚を得て，その卵の人工授精及び稚魚の飼育を試みる以外にないが，これは現在のところでは実行困難である。

とくにわが國では，これまで“マクルラス卵”という名称が神谷（1916）の記載以来，その実体についての批判的な吟味なしに，そのまま容認されてきたので，その所属の問題に関して研究者の注意を喚起するという意味で，この一文を草した次第である。

はたして以上の推論が正しければ，キウリエソは，前述したように，日本海の魚類群集において餌料生物としてきわめて重要な位置を占めていることは，太平洋海域におけるハダカイワシ類と同様であつて，日本海における魚類資源の生産を考察するに当つては重要な項目をなすものであるから，将来この方面の研究が進められる場合に，本稿がなんらかの参考となるならば幸いである。

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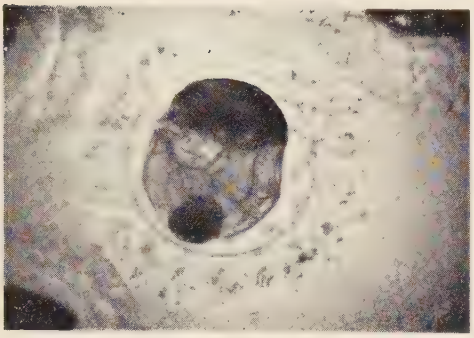

Fig. 1. “Macrurus egg” sampled from the sea. Blastula stage.

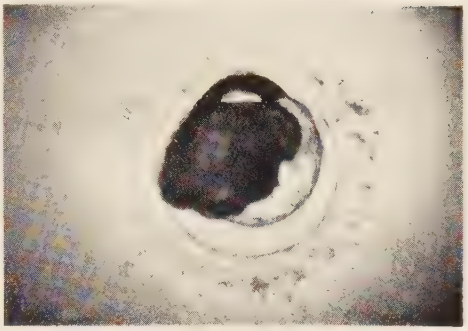

Fig. 2. “Macrurus egg.” An embryo already formed.

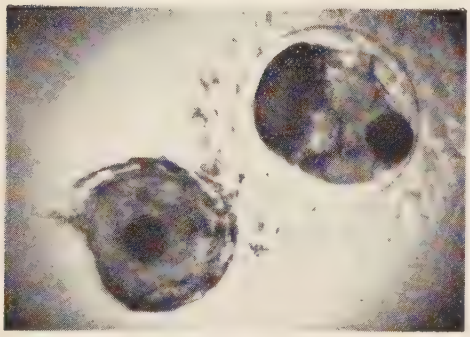

Fig. 3. Left is a matured ovarian egg from *Maurolicus japonicus* ISHIKAWA. A “Macrurus egg” taken from the sea is placed for comparison in the right.

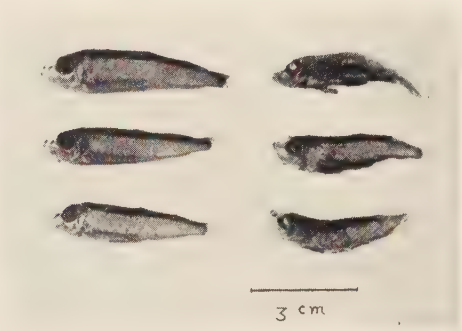

Fig. 4. Left are some specimens of *Maurolicus japonicus* from the catch by set net in Toyama Bay. Right are those found in the stomack of Alaska pollacks.

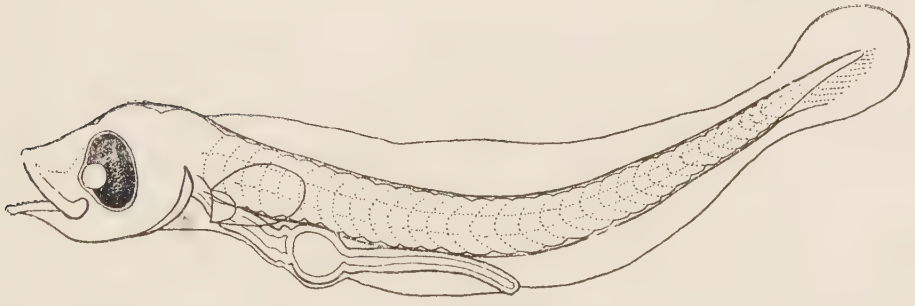

Fig. 5. Larva considered to have been hatched from the so-called “Macrurus egg.” Body length 5.41mm.

Vertical distribution of the floating eggs of *Maurolicus japonicus* ISHIKAWA, a gonostomatid fish, in the sea

By

Saburo NISHIMURA

The egg referred to as *Maurolicus japonicus* ISHIKAWA in the present paper had been called "Macrurus egg" or "Macrouroid fish egg" by previous researchers in this country, for they had believed that it might be spawned by a certain fish belonging to the Family Macrouridae. Recently I pointed out the incorrectness in identifying so and made an attempt to give the correct connection with its spawner, with the result obtained that it might be spawned by a species mentioned in the title belonging to the Family Gonostomatidae, Clupeida (NISHIMURA, 1957).

This species is, though fished only in poor quantity, conjectured to live in great abundance in the deep waters of the Japan Sea; since it is found very commonly in the stomack of various deep layer swimming or bottom dwelling carnivorous fishes such as *Theragra chalcogramma*, *Hippoglossoides dubius*, *Cleisthenes herzensteini* and so forth (KATOH, 1954; NISHIMURA, *op. cit.*).

It spawns pelagic or floating eggs, which are captured by plankton net hauling rather commonly. This floating egg has a gelatinous envelope of peculiar structure, to which is attributed its characteristic confetto like appearance, so it is easily distinguished from the eggs of other species.

During the surveying cruise on board the research vessel of our laboratory in the Bay of Toyama in the spring of 1954, I obtained a considerable number of this egg by net sampling, and was able to acquire some informations concerning its vertical distribution in the sea.

Before going further, I wish to acknowledge my indebtedness to Messrs. Gendi KATOH and Sukekata ITO for reading the manuscript and giving valuable criticisms. My grateful thanks are also due to Messrs. Kazuharu WATANABE and Shogo KASAHARA who were eager to help me in the tedious works of sampling the materials. Further I wish to express my hearty thanks to Capt. Ichisaburo TSUNA and the crew of the research vessel "Asahi-Maru II".

Method of sampling

The sampling of the eggs was carried out with a gear especially designed for

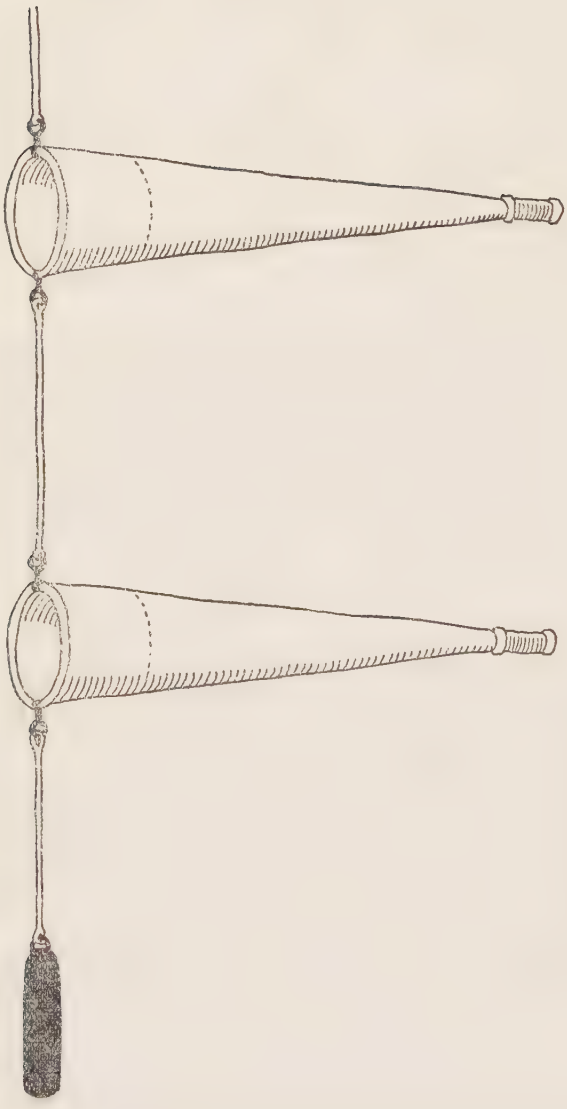

Fig. 1. Schematic representation of the sampling gear used in the experiments.

the purpose of studying the vertical distribution of plankton in the sea. The gear was made up of seven small conical nets which were joined together one to another with a flag line as in the way shown in Figure 1. The mesh size of the bolting silk was nearly equivalent to No. 3 Müller gauze, the caliber and the length of the nets being 20 cm. and 100 cm. respectively. A plumb was attached to the tip of the flag line and was sent down perpendicularly into the sea, so that the nets might sample the plankton at seven different depths.

During the sampling, the ship was laid at anchor, so the plankton organisms which had been driven by water currents only were filtered through the silk and were caught; that is, the gathering of plankton was resorted wholly to the transportation by water currents. This method of sampling was conveniently called „horizontal drift".

In addition to the samplings by the above-said method, "stepped vertical" haulings with a plankton net of an ordinary type were also carried out. Namely, at every sampling time, four vertical haulings were successively made from 10 m., 25 m., 50 m. and 100 m., respectively, to the surface. The mesh size of bolting silk of this net is the same as that of the small ones mentioned before, the caliber being 45 cm.

Results

I. May 17–18, 1954.

In the first experiment, the horizontal drift as well as the stepped vertical method were resorted to.

The sampling station was located at a position (37°26.4′ N, 137°25.8′ E) in Toyama Bay where the depth was 130 m.

Throughout the experiment, the sea surface was very calm and the flow was slow, the stray angle of the flag line in the horizontal drifts being small.

Out of 13 horizontal drifts, each of which sampled for 30 minutes at the seven layers of different depths : 3, 8, 13, 23, 33, 53 and 73 meters, only the collection from the 73 meter depth layer in the first and the second drift contained respective one gonostomatid fish egg.

The results from seven trials of stepped vertical hauls are tabulated below. The figures indicate the number of eggs caught.

Depth of haul	Hauling series						
	I	II	III	IV	V	VI	VII
0 ← 10 m.	0	0	0	0	0	0	0
0 ← 25 m.	0	0	0	0	0	0	0
0 ← 50 m.	0	0	0	0	0	0	0
0 ←100 m.	1	1	1	0	3	0	0

These reults show that the gonostomatid fish eggs are floating below the mid-depth layer, say, 50 meter layer in this case, and not or very sparsely, if any, above that.

II. May 23, 1954.

In the second experiment, only the horizontal drifts were conducted.

The samping station was located at a point (37°21.8′ N, 137°20.8′ E) in the same bay, the very vicinity to the station in the first experiment. The sea depth was 82 meters.

Throughout the sampling, the water current was steadily very strong, the direction of which was standing and unchanged. The stray angle was large in amount and varied between 41° to 59°.

According to the data afforded by the Wajima Meteorological Station, Wajima, during three days prior to the observation day, wind had blown steadily from north, but with the beginning of May 23 the wind direction suddenly changed, hereafter southern wind prevailing. This change in wind direction was accompanied by a rapid rise in air temperature.

All these phenomena suggest us that a line of discontinuity passed through over this district from May 22 to 23.

Thus, from the oceanographical observation *in situ* and the meteorological records on the preceding days, it was assumed that a steady, uniform gradient

current, caused by piling up or removal of sea water owing to wind transportation, might have been developed from surface to fairly deep layer on that day; and consequently is it supposed either that the variation of the current velocity with depth had, therefore, been rather small, presumably negligible for drawing an outline of the vertical distribution of plankton from the results by this sampling method, or, as is more likely the case, that the velocity had gradually been lowered with increasing depth.

The number of eggs that were caught after 30 minutes' drift is given in the following table, in which the figures indicated as "depth sampled" are the approximate depths of sampling in meter corrected for the mean stray angle of the flag line.

1st drift, 6:15–6:45, Mean stray angle 43°							
Depth sampled (m)	2	6	10	17	24	39	53
Number of eggs	0	0	0	0	0	2	50
2nd drift, 8:00–8:30, Mean stray angle 48°							
Depth sampled (m)	7	10	13	20	27	40	54
Number of eggs	0	0	0	0	0	0	2
3rd drift, 10:00–10:30, Mean stray angle 49°							
Depth sampled (m)	7	10	13	20	26	40	53
Number of eggs	0	0	0	0	0	1	13
4th drift, 12:00–12:30, Mean stray angle 48°							
Depth sampled (m)	7	10	13	20	27	40	54
Number of eggs	0	0	0	0	0	1	12
5th drift, 14:00–14:30, Mean stray angle 48°							
Depth sampled (m)	7	10	13	20	27	40	54
Number of eggs	0	0	0	0	0	1	34
6th drift, 16:00–16:30, Mean stray angle 48°							
Depth sampled (m)	7	10	13	20	27	40	54
Number of eggs	0	0	0	0	0	0	32
7th drift, 18:00–18:30, Mean stray angle 57°							
Depth sampled (m)	5	8	10	16	21	32	43
Number of eggs	0	0	0	0	0	3	15

Namely, from the waters shallower than 30 meters, no egg was sampled; for the 30–49 meter and the 50–59 meter depth layer, on the other hand, the mean number of eggs caught in a single drift was 2.9 and 23.8, respectively. When the vertical change in current velocity, if any, is taken into account, the actual increase in the relative distributional density of eggs with increasing depth might be somewhat more radical than the above-given apparent grade of increment.

Discussion

As for the vertical distribution of the gonostomatid fish egg or the so-called "Macrurus egg" in the seas adjacent to Japan, there have scarcely hitherto been

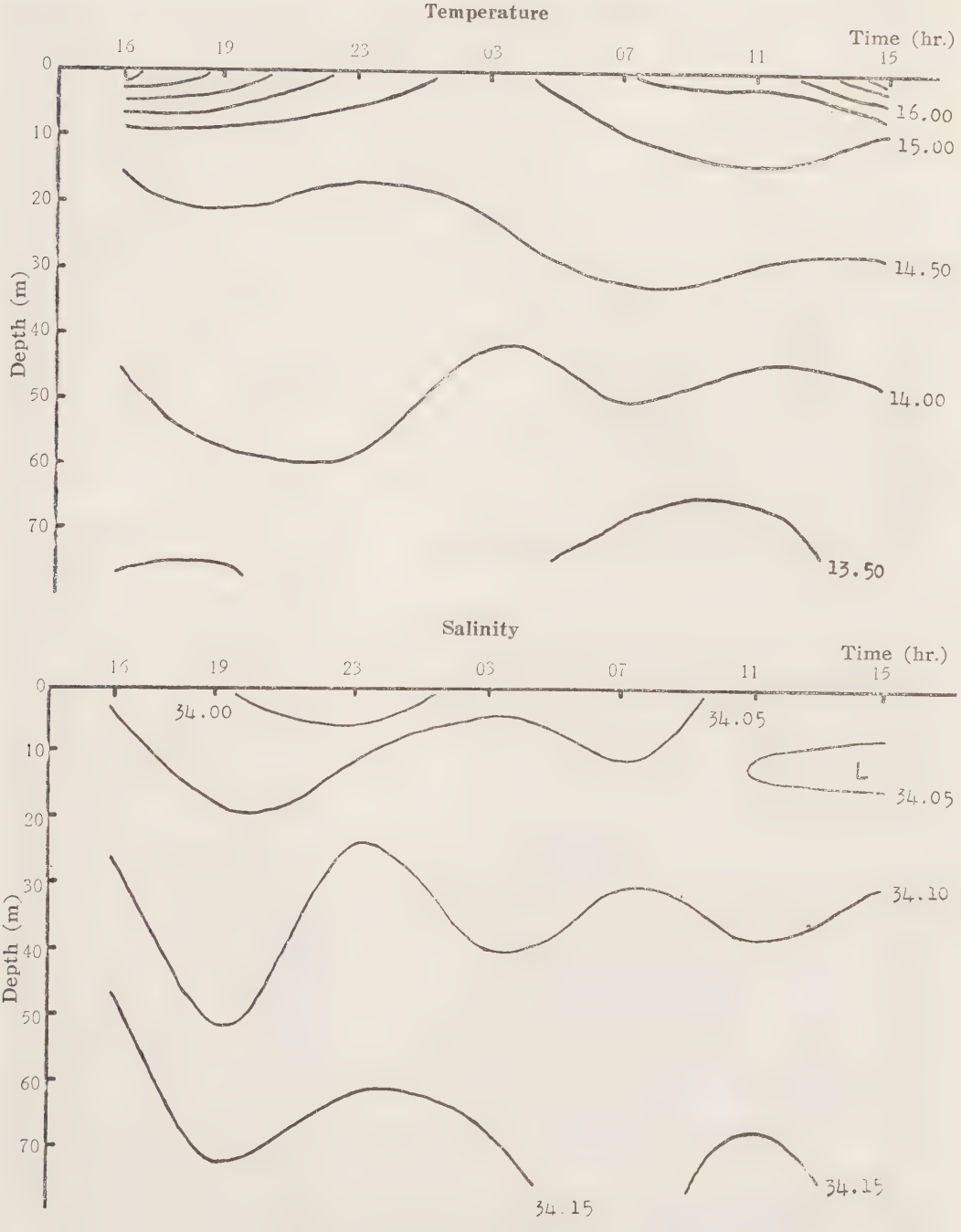

Fig. 2A. Temperature and salinity distributions on May 17–18.

any particular studies. Only KAMIYA (1916) and ITO *et al.* (1951), both of whom, however, had committed an error of referring these eggs to a macrouroid fish, conjectured, from the results of the catches in the Bay of Tateyama and in the Noto Peninsula to Sado Straits area respectively, that the eggs might have been spawned in the deep sea, as their parents were abyssal forms, and gradually floated upwards to a certain depth or sometimes transported even to the surface by upwelling currents, and surmised that the "Macrurus eggs" might be more abundant in the deeper layers than in or near the surface.

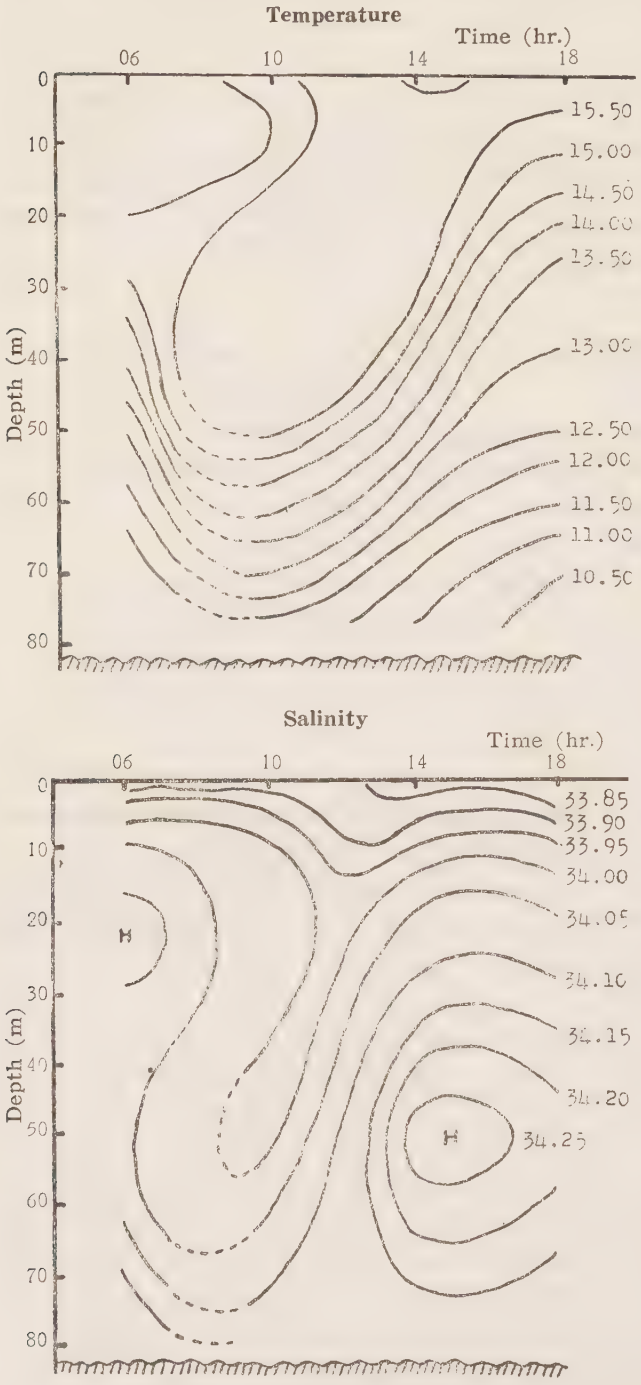

Fig. 2B Temperature and salinity distributions on May 23.

The present study now can be said to have given a positive proof to their conjectures, in so far as they regarded these eggs as the floaters of subsurface layer rather than of surface. From the data given before, particularly from that of the second experiment, it is quite clear that the above-mentioned is actually the case. Concerning the spawning depth, however, I have shown elsewhere that these eggs cannot be spawned in the great depth but that they must be spawned in a relatively shallow layer (NISHIMURA, 1957).

Attention may then be concentrated on the hydrographic correlation. Below are given the charts of water temperature and salinity distributions when the sampling was made (Fig. 2), together with their T - S diagrammatic representations (Fig. 3).

From Figure 2, it can be soon recognized that on May 17–18 both water temperature and salimity changed gradually and monotonuously with depth and time, and that on May 23, on the other hand, the changes in these values were rather abrupt and their distributions were very complicated.

Inspection into the T - S diagrams further reveals the following with respect to water mass distribution. In the first case, three types of water masses are to be discriminated in the layers shallower than 75 meters: the warmer and less haline Surface water (S) in the upper layer, the colder and more haline Warm current water (W) in the deeper layer, and lastly the water of intermediate nature occupying most of the mid-depth layers which might be mixture of the preceding two waters and hereby called Mixed water I (MI). The core of the warm current would be located a little deeper (Fig. 3A).

In the second case (May 23), as might be seen from the complicated temperature and salinity distributions, "shiwo-me" or a convergence passed through the station in the course of time 10 to 14 hrs. with a marked submergence of surface water into the deep layer, the distal portion of which went in direct contact with by far the colder and less haline water near the bottom. The latter water is considered to have been formed as a result of thermal convection during winter, though slightly raised in temperature from its original degree through vernal vertical mixing with the upper warmer waters, and hence is tentatively called "Central water". Thus, in this occasion, five types of water masses are possibly distinguishable: Surface water (S), Warm current water (W), Mixed water I (MI), Central water (C) and Mixed water II (MII). The last is the mixture of the first and the fourth water type (Fig. 3B).

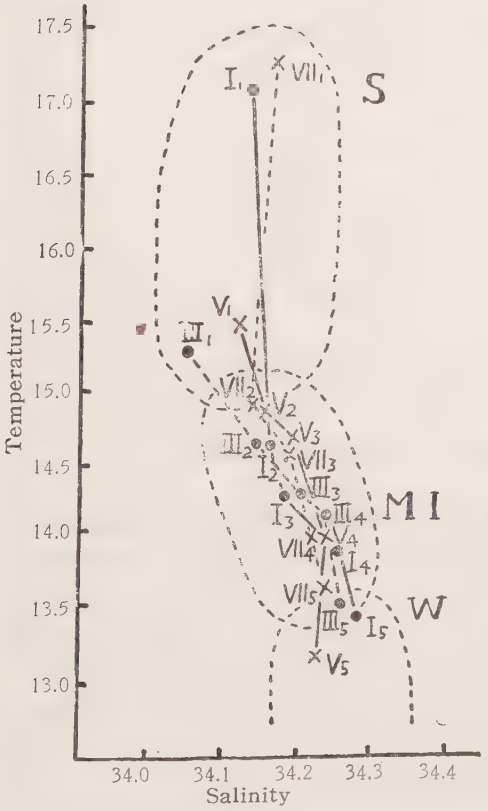

Fig. 3A. T - S diagrammatic analysis of water types. May 17–18.

Now attention may be turned to the possible relationship between the water

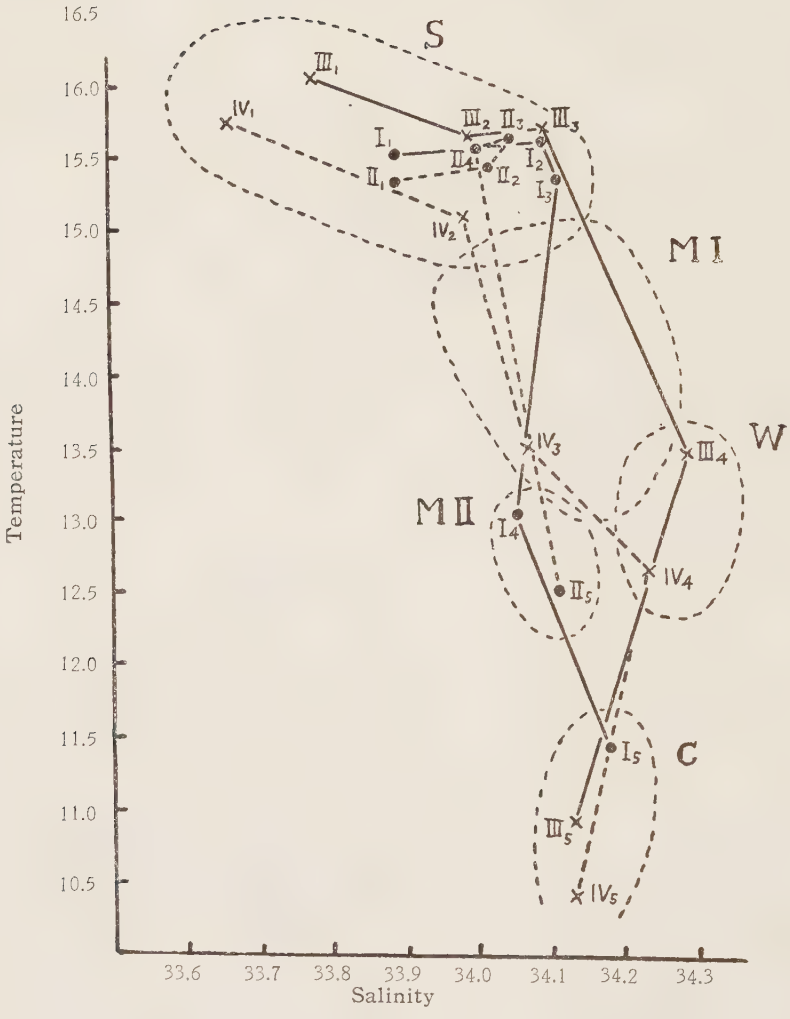

Fig. 3B. T-S diagrammatic analysis of water types. May 23.

types and the relative numbers of eggs contained in them. Below are, for reference, given the equal captivity curves of eggs in relation to depth and time in the second experiment (Fig. 4). For the sake of simplicity, it is postulated that the variation in current velocity with depth is small enough to neglect. We see from this figure that Mixed water II (I4 and II5) contained about 30–50 eggs, Warm current water (III4 and IV4) 15–30 eggs, Mixed water I (IV3) about one egg and Surface water (all excepting the above-cited as well as I5, III5 and IV5) contained none with the exception of II4, which contained extraordinarily some 10 eggs.

This may suggest the gonostomatid fish eggs would be contained in larger amount in the Central water (I5, III5 and IV5) which were though not tried to sample

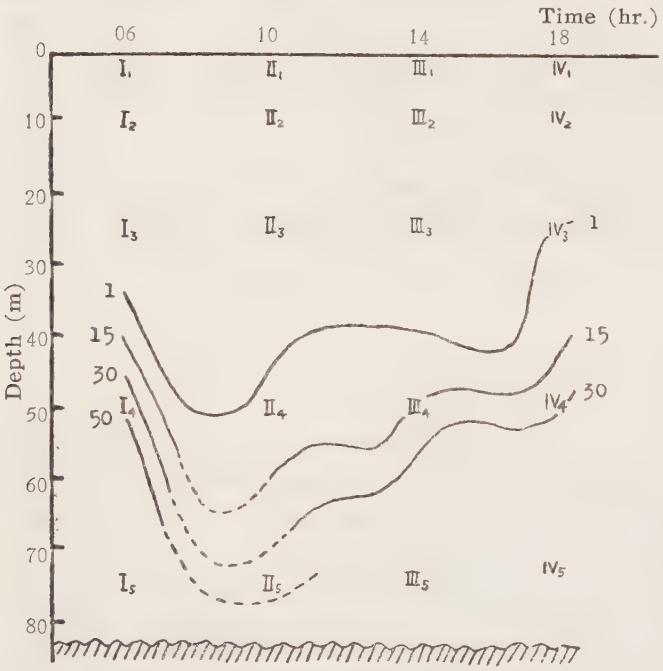

Fig. 4. Equal captivity curves of the gonostomatid fish egg.

this case, since it seems more valid to think that the eggs would have their center of abundance in the Central water and would have been shifted from that to both the Mixed water II and the Warm current water through vertical mixing or diffusion, than to think that the Mixed water II, which is considered to be hardly formed except when active upwelling or sinking taking place and therefore to be temporary nature, would be the center of their distribution.

On the other hand, the gonostomatid fish egg is known to be sometimes sampled by surface towing (NISHIMURA, *op. cit.*). In the Japan Sea, Wakasa Bay and Toyama Bay are especially remarked for the frequent occurrence of this fish egg in the surface or very near the surface, though more abundant eggs no doubt are expected to be distributed in the deeper layers.

This speciality may perhaps be interpreted by taking into account the distinguished development of upwelling in these bays; that is, in the region where upwelling is prevailing along with the ascent in Central water, the matured gonostomatid fish which is a marked representative of the so-called twilight fishes would be allowed to go up further nearer to the surface at night and would spawn, with the result that its eggs would be found floating very near the surface or even in the surface itself, kept off from sinking down as the surrounding water is heavy enough to retain them buoyant. Thus, concerning the cause of the rich and frequent appearance of the gonostomatid fish egg in the upwelling region, I am somewhat divergent in view from ITO *et al.* (*op. cit.*).

It may thus conclusively be stated that the gonostomatid fish eggs are contained mostly in the Central water, and that where upwelling is prevailing the fish eggs would get within the bounds of possibility to be captured from the upper layers, even from the surface.

What is then the cause for the limitedness to or the preference of the subsurface

sea waters in their intact distribution ? KAMIYA (1916) observed that these eggs sank down in standing sea water. This informs us that the eggs are larger, and undoubtedly slightly larger, than the surface water in specific gravity, and that as a result they will go down, even if once brought up to the shallow layers, into the deep waters until they will arrive at the depth where they may get kept in balance with the water around as to the buoyancy, thus leading to the understanding that the specific gravity of the eggs may be responsible for their characteristic vertical distribution in the sea.

Summary

1. The gonostomatid fish eggs found in the Bay of Toyama are distributed in the subsurface layers, and not or very sparsely, if any, in or just beneath the surface.

2. From the T - S diagrammatic analysis, it has been shown that the eggs might have the Central water as the core of their abundance.

3. The specific gravity of the egg may be responsible for the limitedness to or the preference of the subsurface sea water in its vertical distribution. Namely, it is estimated to be slightly larger than that of usual surface water, with the above-mentioned pattern of distribution resulting.

4. In the region where upwelling is prevailing, however, the eggs which have been spawned by adult fishes coming up till the proximity of the surface at night may be retained there and get within the bounds of possibility to be sampled also from the surface layers.

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Studies of the Conditioned Reflex in the Lower Vertebrates

IV. Differentiation in Gold-fish [1) 2)]

By

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In our previous paper, which is one of a series of studies on the conditioned reflexes in the lower vertebrates, we stated that the temporary connection between food and light is easily established, although the rate and form of its formation is quite variable among individual animals, while the extinctive inhibition is much more difficult to be worked out. It explicitly seemed to reveal the fact that the formation of the negative conditioned reflex, if at all possible, is not so easy as that of the positive one (Tuge and others, '55). Henceforth, it should bring forward the problem of how the varied types of internal inhibitions develop phylogenically as well as ontogenically.

Biryukov ('55) stated that it is possible to form differential inhibition in carps, but, generally, it is very unstable and hard to be retained to the day following experimentation. On the other hand, Voronin ('54, '55) and others did not find it dificult to work it out in fish. Our observations made upon sea bream, which possesses a most highly developed brain among fish, support their findings, but we were rather sceptical, in so far as other forms of fishes were concerned. The problem in consideration is not yet settled.

We are of the opinion that a disclosure of the mechanism of the internal inhibition is a matter of the greatest importance not only in the lower vertebrates, but as well as in the higher forms (Tuge, '56).

In the present paper we deal with the process of differentiation and the changing of signal denotations of stimuli, using the motor-food conditioned reflex in gold fish.

For the present study were used six gold-fish of 2 to 3 years of age. They were kept in our laboratory for about half a year before the experimentation. The appa-

1) Aided in part by a grant from the Ministry of Agriculture and Forestry.

2) Acknowledgement is due to Mr. TACHIBANA, Seiitsu, for his self-sacrificing assistance.

ratus and method by which the experiments were made almost the same as designed by Prazdnikova ('53 a, b). A fine thread with a bead, having been introduced in the experimental aquarium, 40 x 30 x 22 cm, is occasionally pulled by the fish. This pulling is coupled with bait. The bait, which is stiffened with a commercial foodpowder sold as a special feeding for fish, is poured into the aquarium through a funnel which is constructed at a place higher than the aquarium. The bait poured into the aquarium by means of jet water-flow drops into a feeder, which is made by enclosing the three sides with white celluloid plates.

As conditioned stimuli, both electric bulbs of red and green lights are used. This light illuminates the aquarium from the outside. The intensity of the light in both cases of red and green was about 7 luxes at the center of the aquarium and about 10 luxes at the feeder.

The present experiments were undertaken from October 1955 to March 1956. Temperature in the experimental aquarium throughout the experiments was kept at 7.5~17.0°C.

A thread with a bead was connected through an electric wire with a lever, so as to register mechanically the pecking reaction of the fish on the kymograph. However, in cases in which the pecking would not be strong enough to move the lever, it was necessary to supplement such slight reactions by means of another circuit, through which they were registered by automatical handling.

Prior to performing the conditioned connection between light and food, the pecking reactions were coupled with food. After several repetitions of this coupling, the fish were reinforced with food only when they pecked the bead, during stimulation of light.

The speed of a food-conditioned reflex thus formed in the gol -fish, is shown in Table 1. The formation of the temporary connection is shown in Fig. 3. As the Table shows, some of the fish failed to combine the light with food through the agency of pecking (*G. no. 112, G. no. 119*). In most cases they swam up to the feeder directly by an application of the conditioned stimulus, without pecking the bead. Others also failed to obtain the conditioned connection stable enough to make the experiment of differentiation (*G. no. 117*). As can be readily imagined, it appeared much more difficult to work out the food conditioned reflex by means of the so-called "food-getting" method (Voronin, 1954) than in the previous experiment. Here, we also may point out in our data, that, generally, many more repetitions of reinforcement were needed to establish a stable temporary connection, than those needed by Prazdnikova ('53 a), to obtain the same results.

In reality, it would not be easy to compare our data with those of Prazdnikova. Vatsuro ('54) suggested that there is an ambiguity in the expression of the speed of formation of the temporary connection by Prazdnikova.

For the experiment on differentiation, we used three fishes in which a stable

Table I

Speed of formation of the temporary connection and the differentiation observed in the gold-fish experimented upon

Cases	Formation of temporary connection			Formation of differentiation between two stimuli (red and green)					
	Number of stimuli required for primary formation of the temporary connection	Number of stimuli required for the establishment of stable temporary connection	Number of stimuli applied prior to differentiation	Number of stimuli applied prior to differentiation		Number of stimuli required for establishment of differentiation		Number of stimuli applied prior to differentiation	
				Positive	Negative	Positive	Negative	Positive	Negative
G. no. 111	38	66	308	17	22	35	46	235	349
G. no. 112	29	—	114						
G. no. 113	38	55	102	55	70	106*	128*	276	516
G. no. 114	13	75	96	18	24	38	54	77	106
G. no. 117	47	70	157						
G. no. 119	—	—	31						

Asterisks indicate that stable differentiation has not been worked out.

conditioned reflex had been established, with either red or green light. One out of three fishes (*G. no. 113*) generalized at a rate of 100% at the first application of a negative (differential) stimulus (Fig. 2), while the others did not do so entirely. But one fish, which did not show any generalization at all, was apparently effected by an intensive orientating inhibition, which caused an interruption of generalization. However, much to our regret, we have to diesist further disserting upon this matter, since our data are not conclusive enough for this purpose.

To work out the differential inhibition, the previously conditioned stimulus was continued with the accompaniment of food, while the differential stimulus was not reinforced with food. That is to say, the former is a positive stimulus, while the latter is a negative one. In connection with the afore-mentioned, we considered it as a formation of differentiation when a ratio of over 60 % in discrepancy between reactions to the negative and to the positive stimulus was established.

Among those experimented upon for differentiation, two fishes were found to have been relatively quickly and well established in the differentiation

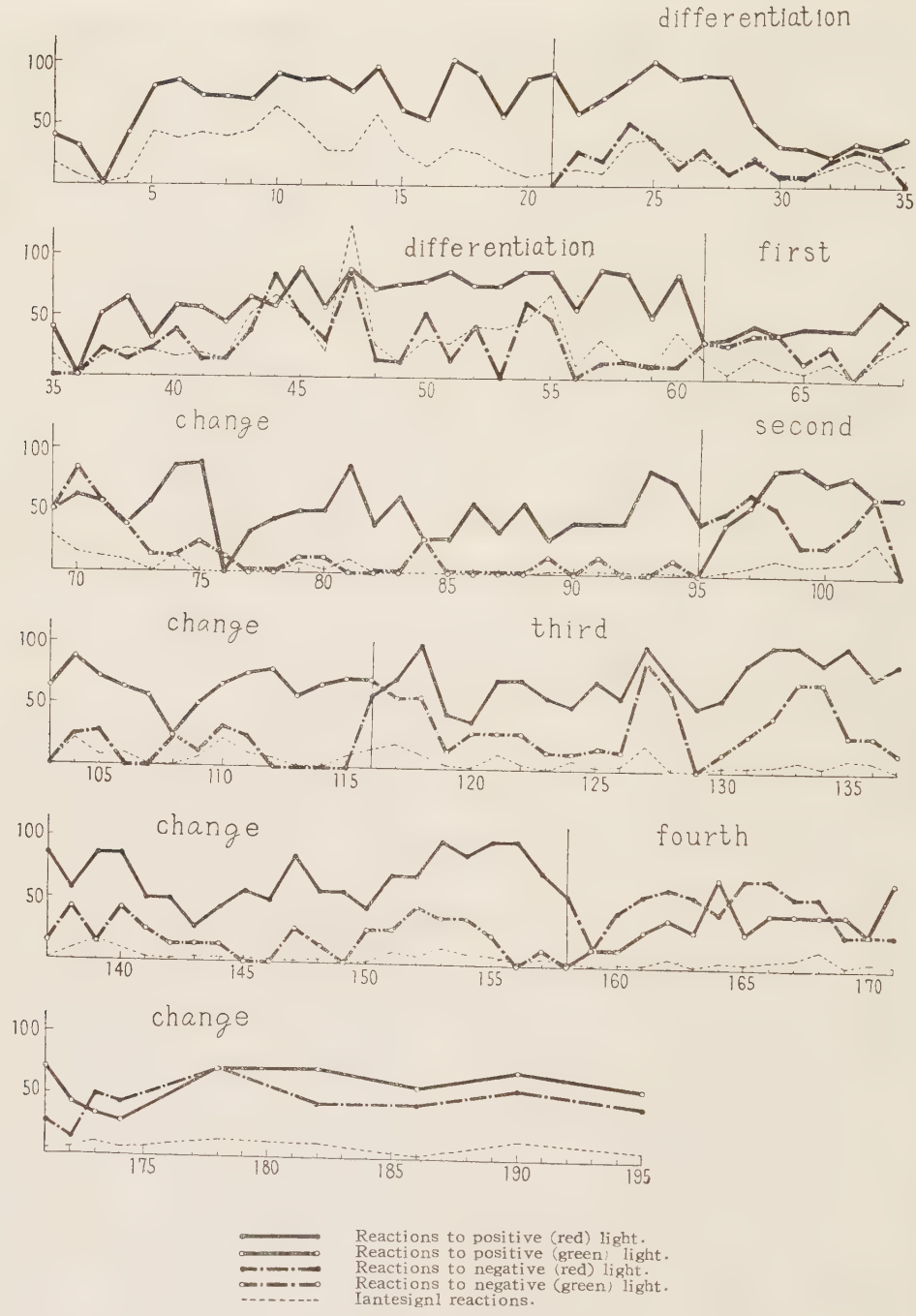

Fig. 1. Graph showing the entire course of experimentation in a gold-fish (*G. no. 111*). The differentiation was worked out by application of differential stimuli. However, in the course of differentiation, sometimes it was destroyed and sometimes re-established. Four changes of the signal denotations of stimuli were made. Ordinate indicates the number of peckings in per cent to the positive stimulus and the negative stimulus, and the number of intersignal reactions in one series of experiments; abscissa, days.

between colors. The course of differentiation in a fish (*G. no. 111*) is shown in Fig. 1. The differentiation in this fish was established by 46 repetitions of the differential negative stimulus (red) and by 35 repetitions of positive stimulus (with reinforcement of food). As is seen from the figure, differentiation, once formed, is destroyed and again re-established. To work out a stable differentiation, were required more than 251 repetitions of the negative stimulus. After 349 repetitions of the negative stimulus and 235 repetitions of the positive stimulus, the fish was experimented upon with a changing of the signal denotations of stimuli. Reference to this will be made later.

In an other case, (*G. no. 114*), differentiation was formed after 54 repetitions of the negative stimulus (green) and 38 repetitions of the positive stimulus (red). Afterwards this differentiation was not destroyed. After 106 repetitions of the negative stimulus and 77 repetitions of the positve one, the changing of the signal denotations was undertaken.

Concerning the last one, (*G. no. 113*), it formed the differentiation after 128 repetitions of the negative stimulus (green) and 106 repetitions of the positive one (Fig. 4), but, soon after, it failed to persist in the differentiation. The course of differentiation is shown in Fig. 2. Although 516 times of the negative stimulus and 276 times of the positive one were applied to it for about 70 days, no distinct differentiation was made. Accordingly, the experiment for changing the signal denotations proved to be impossible.

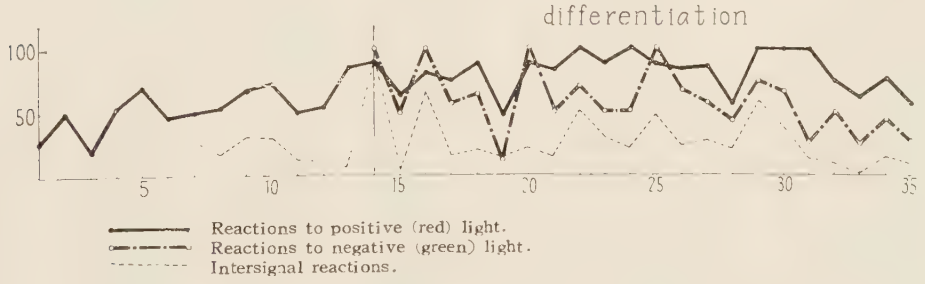

Fig. 2. Graph showing an example in which a total generalization was observed by the first application of differential stimulus (*G. no. 113*). Ordinate indicates the number of peckings in per cent to the positive stimulus and the negative stimulus, and the number of intersignal reactions in one series of experiments; abscissa, days.

As follows from the above mentioned, it appeared very difficult to work out a differentiation in gold-fish. This result, however, is quite different from that made Prazdnikova ('53 a). According to her results with *Carassius*, the differentiation is formed relatively quickly and stably. Why such a difference is found, requires further study.

The changing of the signal denotations of stimuli was made on the fish, (*G. no.*

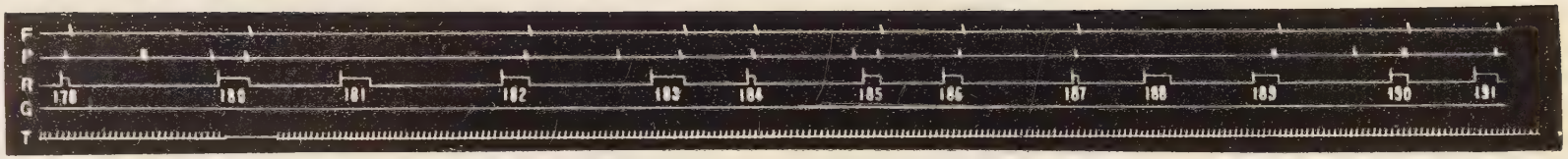

Fig. 3 Showing a formation of the temporary connection, 13 days after the beginning of experimentation. (*G. no. 113*) (20. XII, 1955) Abbreviations; F, reinforcement of food; P, pecking reactions; R, red light (conditiond stimulus); G, green light (conditioned negative stimulus); T, time (6 seconds). In the Fig. 3, numerals denoting on the line R indicate the number of application of conditioned stimuli (Positive) from the beginning of experimentation.

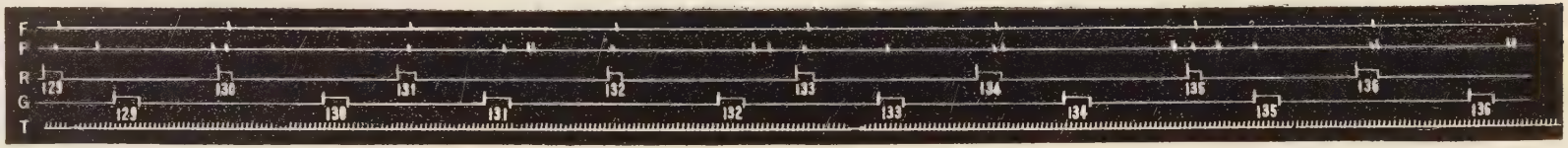

Fig. 4 Showing formation of differentiation, 18 days after introduction of the differential stimuli, (*G. no. 113*) (20. I. 1956). Numerals denoting on the line G indicate the number of differential stimuli (negative) and both the lines, G and R, give the number of stimuli from the beginning of differentiation. Other abbreviations are the same as in Fig. 3.

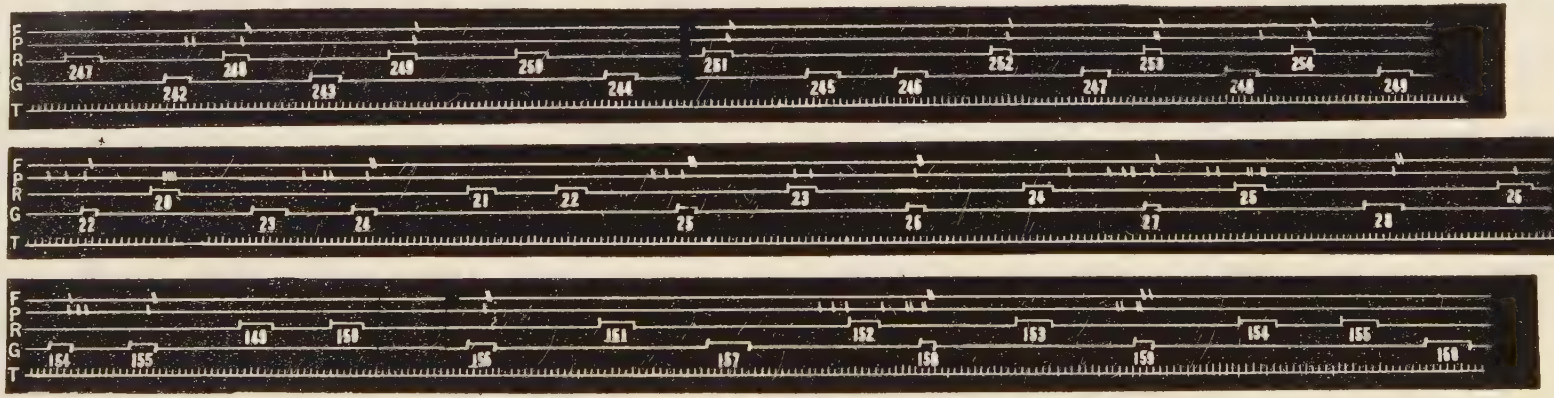

Fig. 5 Showing an accomplishment of the first change of the signal denotations of stimuli (a), the generalization at the second change (b), and an accomplisment of the second change (c), (*G. no. 111*); a, 34 days after the introduction of the first change. (14. II, 1956) b, 4 days after second change, but the differentiation was not established (18, II, 1956). c, Differentiation became complete 21 days after the second change. (6, III, 1956) In *a* of the figure, numerals denoting on the line R indicate the number of application of positive conditioned stimuli and the line G, that of negative conditioned stimuli applied from the beginning of the first change. In *b* and *c*, numerals denoting on the line R indicate the number of negative stimuli and the line G, that of positive ones in the second change.

111), as stated above. At the first change, the differentiation began to be appeared after 99 repetitions of the negative stimulus (green) and 47 repetitions of the positive stimulus (red), but it slightly decreased and then again increased to a certain extent (Fig. 5 *a*). After 249 repetitions of the negative stimulus and 124 repetitions of the positive stimulus, further experiments were made for the second change of the signal denotations. At the second change it was noticed that the changing appeared to be performed by a relatively smaller number of stimuli (Fig. 5 *b*), that is to say, by 26 repetitions of the negative stimulus (red) and 13 repetitions of the positive one (green.) But it required many more repetitions of stimuli to accomplish a sufficient change of signal denotations. In the course of the second change the changing was destroyed twice as shown in Fig. 1. After 155 repetitions of the negative stimulus and 101 repetitions of the positive stimulus it was transferred to the third change (Fig. 5 *c*). At the third change, the changing seemed to be accomplished after 65 repetitions of the negative stimulus (green) and 41 repetitions of the positive stimulus (red). However, it was once destroyed. After this the changing was settled by many repetitions of the positive and negative stimuli. The fish was transferred also to the fourth change after 304 repetitions of the negative stimulus and 217 repetitions of the positive stimulus throughout the third change. At the fourth change, although it was applied by 119 repetitions of the negative stimulus (red) and 42 repetitions of the positive stimulus (green), any indication of the possibiblity of the changing the signal denotations of stimuli was not found (Fig. 5 *c*). Further experimentation was not undertaken. Accordingly, we could not ascertain whether or not the changing was possible. According to our suggestion, however, further changing would not be impossible if a great deal of repetitions of the stimuli would be applied.[1)]

The experiment for changing the signal denotations for the fish (*G no. 114*), was quite difficult to make. In fact, it did not show any sign that the changing of the signal denotations had been established, in spite of the application of a large number of stimuli, that is, 370 times of the negative stimulus (green) and 83 times of the positive (red). Afterwards, both the negative and positive conditioned reflexes seemed to be destroyed, so that further experiments were not made.

According to our results, the intersignal reactions very much increased at the beginning of the experimentation and did not decrease to much even when the conditioned connection had been established. When the differential stimulus was introduced, the frequency of intersignal reaction did not reveal any apparent variations, although there appeared to be a slight indication for increase. Even when the changing of the signal denotations was made, a noticeable rise of the intersignal

1) In April 1956, Dr. Prazdnikova, at Koltsushi, Pavlov's Physiological Institute, U.S.S.R., told one of the authors (H. T.) that she succeded in changing the signal denotations of stimuli 8 times in the only one of gold-fishes experimented upon.

reactions was also not observed (Fig. 1.). It may be interesting to note that the intersignal reactions in the three fishes were extinguished after a great number of times, they were elicited as follows; 1870 times (76 days after experimentation) in *G. no. 111*, 910 (48 days) in *G. no. 113*, 450 (41 days) in *G. no. 114*.

Although the intersignal reactions of pecking were caused by the excitatory state of the food center, the above figures seem to indicate that the decrease of the reactions depends upon the formation of extinctive inhibition after a long period of time. Since the present experiments were made mostly in the winter time, further investigation may be needed to determine whether or not the decrease of the intersignal reactions is due to the lower temperature, and, or, to the bodily changes of the fishes.

According to the above mentioned results, generally speaking, the process of internal inhibition develops but in an unstable form. Even though differentiation between colors is possible, differential inhibition is only produced when the differential stimulus is applied a great number of times, otherwise it fails to develop into a distinct form.

As already stated, our results seem to be different from those obtained by Prazdnikova ('53 a) and Tretyakova ('53). According to Prazdnikova, stable differentiation between colors is formed by application of 20 to 40 times of differential stimuli, and according to Tretyakova, it requires also 15 to 76 times of stimulus. In both cases, gold-fish were used.

On the other hand, the same experiment with carps in Biryukov's Laboratory seems to be well in accordance with our own. That the process of internal inhibition is less well developed in gold-fish, has also been ascertained in our previous experiment on the extinctive inhibition in the same fish. However, it should be emphasized that one of the internal inhibitions, that is, the mechanism of differential inhibition, is not always the same in various kinds of fish. For instance, in sea breams the differentiation is established more quickly than in gold-fish, and is relatively stable.

Tretyakova ('53), studying the changing of the signal denotations of stimuli from a point of view of comparative physiology, reported that only one out of three gold-fishes was successful in being changed, while others failed to be so. At the first change, the change became stable after 29 repetitions of negative stimulus and at the second change after 150 repetitions. However, it was impossible to establish the third change, the conditioned reflex having been destroyed. In two other cases, even in the first change the changing was unsuccessful, in spite of 220 and 178 repetitions of negative stimulus, respectively. These results seem to be the same as ours. It shows that, although there are highly individual variations, mobility of the nervous activity is less well developed in fish. It may be added in this connection that with the sea bream, too, it was difficult to change the signal

denotations. As to the problem of mobility, we observed that the gold fish, as well as the sea bream, displayed a somewhat neurotic state during the first change of signal denotations, and also a disturbance of the positive conditioned reflex, which makes matters worse as far as the development of the internal inhibition is concerned. This might be explained as a disturbance of the equilibrium of both processes of excitation and of inhibition, which would be caused by the imperfection of mobility in the developmental level, such as in fishes.

Studies of Voronin ('55) dealing with the mobility in the varied forms, from fish to apes, are very instructive. Judging from the speed required for the successive changes of signal denotations, he drew the conclusion that the mobility revealed by the first change does not run parallel to the developmental level of nervous systems in the different animals examined, even though a slight difference may exist. But, the degree of the disturbance of mobility caused by the successive changings is thought of as an index of the developmental level of animals. The data cited by Voronin, however, according to our suggestion, seem rather to conclude that the variations of mobility are appreciated throughout different forms of animals, that is to say, the mobilty in the fish is exceedingly lower than that in birds (Tuge and others, '56).

Frolov ('38) concludes, on the basis of his accumulated data dealing with fish, that it is very difficult to establish the internal inhibition and, at best an unstable one, the extinctive inhibition appearing in a wave-like form, which, as yet, indicates the weakness of the nervous process. Furthermore, he states that, from a point of view of animal phylogeny, strength of the nervous process is developed most quickly, while, among strength, equilibrium and mobility of the nervous process, mobility is the slowest to develop.

According to our results with fishes, in addition to those with birds, we strongly support the conclusion drawn by Frolov, and emphasize that the discrepancy of the results found among the investigators dealing with fish should be fully clarified in the near future.

SUMMARY

1) Motor-food conditioned reflex was studied with gold-fishes, in order to make a temporary connection between food and light (green and red), by means of the so-called "food-getting" method, in which the fish is conditioned to pull a bead and then to eat.

2) To form a temporary connection by using the food-getting method, seemed to be slightly difficult; a few of the fishes experimented upon, failed to establish the temporary connection through the agency of pulling. The speed of formation

of a stable temporary connection varied individually, but roughly 55 to 75 repetitions of reinforcement were necessary. It did not seem to according to the colors used.

3) Generalization after the first application of differential stimulus showed a remarkable difference in individual fishes. One exhibited 100 % of generalization, but the others did not at all. It may be suggested that this is due to the degree of orientating inhibition.

4) It was found to be extremely difficult to establish a stable differentiation.

5) In the successive changes of the signal denotations of stimuli, changing more than three times was successful in one case only. An alteration of the previously positive stimulus to negative one seemed much more difficult than the reverse. In each changing of signal denotations, either the positive or the negative conditioned reflex was difficult to establish, in comparison with the higher forms of animals. It indicates that the process of internal inhibition is remarkably weak in fishes.

6) The intersignal reactions take quite long time to be extinguished.

7) Mobility of the nervous system in fishes is discussed from the view point of the developmental level of animals.

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Studies of the Conditioned Reflex in the Lower Vertebrates V. Respiratory Defensive Conditioned Reflex in Carp[1)2)3)]

By

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It has been noted in our previous papers dealing with the food conditioned reflex, that the number of reinforcements requried for the formation of conditioned reflex in lower vertebrates such as fish is not as accurately determined as in higher animals (Tuge, Ii, Kanayama, and Ochiai, '55; Tuge, '56). In this connection the defensive conditioned reflex may be of much more use.

On the other hand, fish living in water are always under the influence of the surrounding media, through which their activities are greatly modified. Among such media which may be considered harmful to fish, CO_2, acids, sulfides and others may be counted. There are possibilities in the natural conditions showing that such a harmful chemical substance, as an unconditioned stimulus, will cause a defensive conditioned reflex in combination of any indifferent stimuli.

Chernova ('53) succeeded to obtain in carps a defensive conditioned reflex very quickly, by combining CO_2 with light. It is well-known that the CO_2 solution would have influence not only upon the chemical sense organs of the mouth or the body surface of the fish, but also directly upon the respiratory center through the blood circulation. There arises a question as to whether or not such a direct stimulation would be able to establish such a quick and stable temporary connection. If so, CO_2 or H_2CO_3 introduced into the water in excessive quantity may be supposed to exercise a profound influence upon the behavior of fish.

In the pressent experiment, we dealt with the formation of respiratory conditioned reflex under application of CO_2 and HCl as an unconditioned stimulus. The latter will be considered only as a stimulant of the chemical sense organs.

MATERIAL AND METHOD

For the present experiment 17 carps (*Cyprinus carpio*) of one to two years of

1) Read before the 27th Japanese Zoological Meeting, Kanazawa, October, 1956.
2) Acknowledgement is due to Mr. Chang Hui Yueh for his kind assistance.
3) Aided in part by a grant from the Ministry of Agriculture and Forestry.

age were used. They ranged from 17 to 23 cm in body length, including the tail. The experiments were undertaken from July to September. Water temperature was kept at 22–26°C.

For the experimentation, the fish was tied with bands as illustrated in Fig. 1.

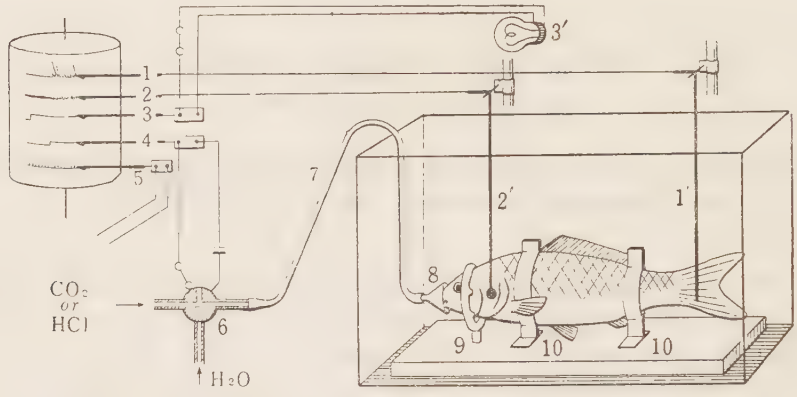


Fig. 1 Arrangement of the set-up for the experimentation. Explanation in the text. 1 – 1′, movement of tail; 2 – 2′, movement of operculum; 3–3′, light; 4, CO_2 or HCl; 5, time; 6, a three-way cock; 7, a tube leading to the small funnel; 8, a small funnel; 9, ring; 10, bands.

The method to tie the fish was according to that of Kogan and Shitov ('54, p. 18). The fish tied as above was placed into an experimental aquarium containing water of about 20 *l*. Both the movements of the operculum and tail were registered on a kimographion by means of the levers, the ends of which were gently placed onto the operculum and the tail respectively.

During the experimentation, water of about 0.8 *l* per minute was constantly poured onto the mouth from a small funnel, to which the tank, filled with water, was connected by a tube. Either CO_2 or HCl solution, used as an unconditioned stimulus, was poured from the respective tanks through the same funnel by means of a three-way cock. The CO_2 saturated solution contained 1.1 g per litre of CO_2, for which titration was made, according to R. B. Warder's method. As HCl solution, the solutions of 1/10,000, 1/1,000 and 1/100 mol were used. However, in the present experiment 1/100 mol solution was used exclusively, since it was most adequate as an unconditioned stimulus.

As conditioned stimuli were applied light, a buzzer and the water current given onto the lateral line. The electric light was suspended far above the aquarium, and its intensity was about 75 luxes at the surface of the aquarium. The buzzer was sounded at about 2 m above the aquarium. Stimulation of the water current was given slantwisely onto the lateral line of the abdominal region, through a small glass tube.

EXPERIMENTAL RESULTS

Experiments with CO_2

Light and CO_2 5 fishes were used for the experiment in order to work out the temporary connection between light and CO_2. The orientation reactions to light, if existing, are easily extinguished, except in only a few fishes. The combination of light with CO_2 was made as follows: 15 to 30 seconds after the light

Table 1

Speed of formation of the temporary connection between the chemical substances (CO_2 and HCl) and the various conditioned stimuli.

Kinds of combination	Cases	Number of reinforcement required for the weak temporary connection	Number of reinforcement required for the stable temporary connection
CO_2 and light	*C. no. 152*	1	2
	C. no. 153	4	—
	C. no. 155	1	2
	C. no. 187	3	11
	C, no. 188	4	9
CO_2 and buzzer	*C. no. 160*	2	4
	C. no. 161	—	2
CO_2 and water current	*C. no. 157*	2	—
	C. no. 158	2	—
	C. no. 164	3–6	—
	C. no. 165	4	5
HCl and light	*C. no. 176*	5	7
	C. no. 181	3	7
	C. no. 182	3	6
	C. no. 184	2	9
	C. no. 185	2	9
	C. no. 186	2	9

was switched on, CO_2 solution was poured onto the mouth for about 10 to 30 seconds. Usually, the temporary connection is formed very quickly. The speed of formation of the temporary connection is shown in table 1. Figure 2 illustrates the kimographic records of the formation of the temporary connection.

Buzzer and CO_2 In two carps used for combining buzzer with CO_2, the temporary connection was formed after 2 times of reinforcement of CO_2, as shown in Table 1.

Water current and CO_2 Four carps were subjected in order to make the temporary connection. As seen in table 1, the temporary connection was established after 2 to 4 times of reinforcement with CO_2. In comparison with the other cases, such as with light and buzzer, however, the stable conditioned respiratory reflex was hardly obtainable. At least, it required more than 5 times of reinforcement to obtain the stable temporary connection (Fig. 3).

Experiments with HCl

Six carps were used to make the temporary connection between HCl and light. In this case, only light was used as the conditioned stimulus. As seen in table 1,

Fig. 2.

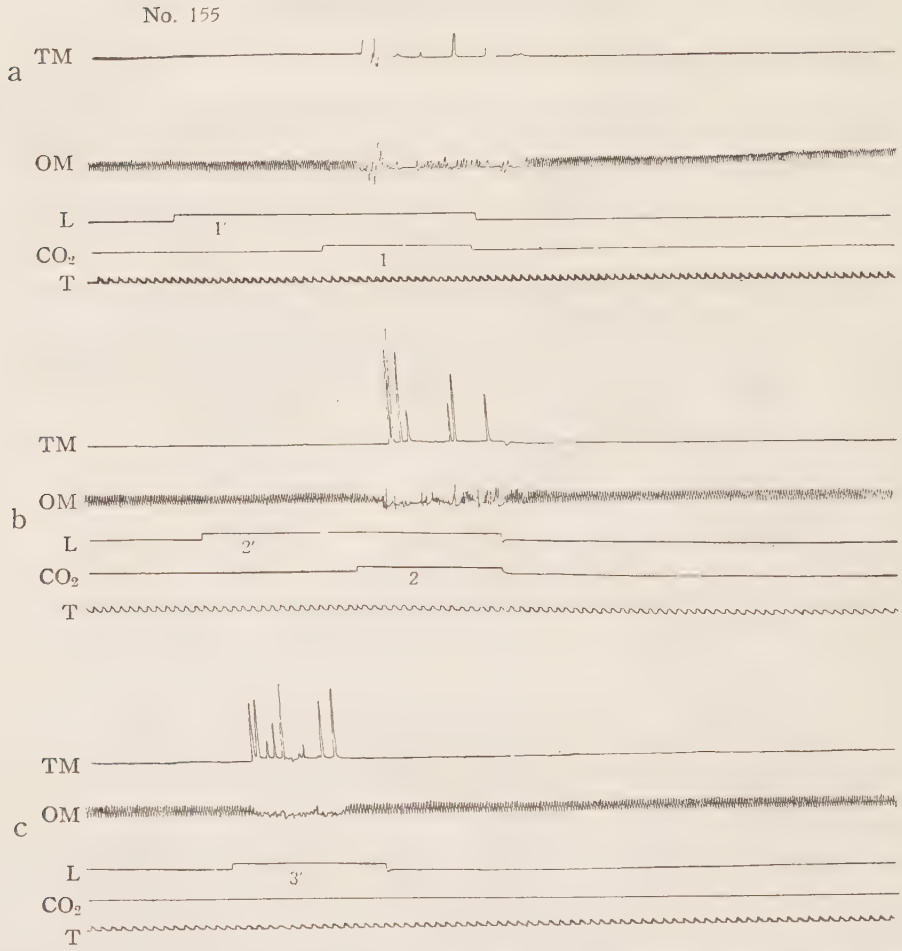
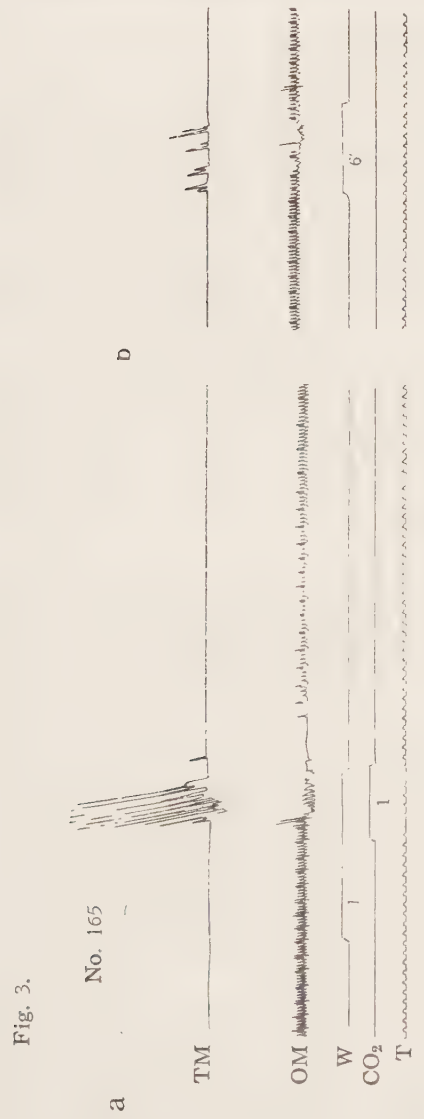


Fig. 2. The figure illustrates the formation of the temporary connection between CO_2 and light. (a) First application of CO_2. (b) Second application of CO_2. Very slight disturbance in the movement of operculum was observed. (c) Application of conditioned stimulus (light) after two times of reinforcement of CO_2. Abbreviations; TM, movement of tail; OM, movement of operculum; L, light; T, time (2 seconds).

the weak temporary connection was formed after 2 to 5 times of reinforcement and, the stable connection after 6 to 9 times of reinforcement (Fig. 4). Accordingly, the formation of respiratory conditioned reflex by application of HCl as unconditioned stimulus is not considered so slow, when compared with the case of CO_2.

Extinction

We could not follow the process of extinction to a complete result, because of certain circumstances in our laboratory. The temporary connection established by CO_2 appeared to be extinguished 9 to 16 times of application of extinctive stimulus without reinforcement of CO_2. It is very interesting in the case of HCl, where it required a large number of extinctive stimuli to extinguish the respiratory conditioned reflex. In one example, it required more than 40 timesof extinctive



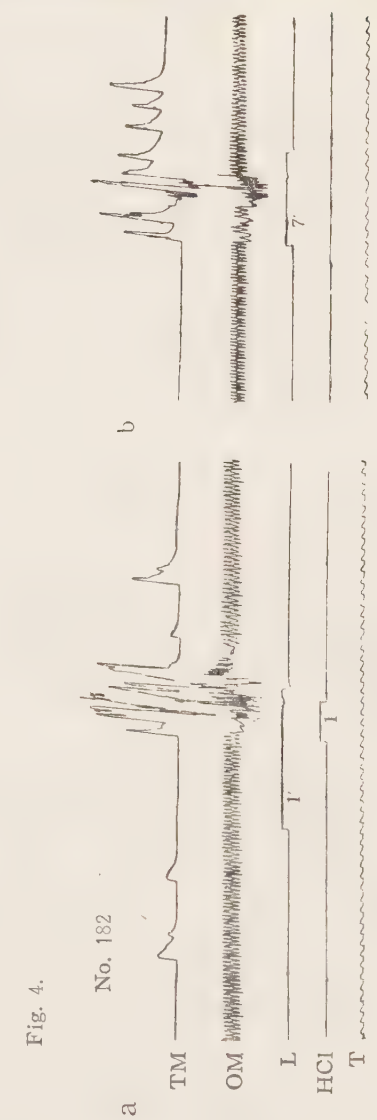


Fig. 3. The figure illustrates the formation of the temporary connection between CO_2 and water current onto the lateral line. (a) First application of CO_2. (b) Conditioned respiratory reflex elicited after 5 times of reinforcement of CO_2. Abbreviations are the same in Fig. 2 except W (water current).

Fig. 4. The figure illustrates the formation of the temporary connection between HCl and light. (a) First application of HCl. (b) Conditioned respiratory reflex elicited after 6 times of reinforcement of HCl. Abbreviations are the same in Fig. 2.

stimuli to attain complete extinction. It is also noted, that the conditioned reflex which had once been extinguished, was again vigorously elicited on the following day. In either case, CO_2 or HCl, the process of extinction appeared to take a wave-like course.

DISCUSSION OF THE RESULTS

According to the results of Chernova ('53), a strong temporary connection was established in almost all the fishes experimented upon, by merely one combination of light with CO_2. Our results, however, differ from those obtained by Chernova, since the former seemed to require over 2 times of reinforcement with CO_2 in order to establish a strong temporary connection in cases where light, buzzer, or a water current was applied as a conditioned stimulus. This may be explained by the fact that there was a considerable difference between the methods employed. Chernova adopted the method of pouring a CO_2 saturated solution at once into the aquarium where the whole body of the fish would receive the full effect of CO_2, together with a sudden change of the water pressure, due to the partial draining of the aquarium. In our method the mouth region of the fish would be locally stimulated at first. However, we can support the conclusion that the temporary connection with CO_2 applied as an unconditioned stimulus, tends to be formed very quickly in the fish.

Even though our materials used for the experiment in combining CO_2 with water current as a conditioned stimulus, were not adequate enough, it seemed not to be easier to do so than with the other conditioned stimuli used, either light or buzzer. If it be true, it would be worth to reinvestigate this matter from an ecological point of view.

In the present experiment, we intended to make it clear whether or not there is a difference in forming the temporary connection, using different chemical substances as unconditioned stimuli with their respective physiological effects on fish, such as CO_2 and HCl. However, we could find but little difference between them, in so far as it concerned the speed of formation of the temporary connection. That is to say, the temporary connection by means of CO_2 might be formed a little more quickly than that by means of HCl.

Detailed examination of the kimographic records obtained showed that the latent period from the stimulation of CO_2 to the reactionary change of the movement of operculum was longer than that in the case of HCl. Roughly speaking, in most cases of CO_2 stimulation, the latent period is from 2 to 8 seconds, while in the cases of HCl, it is within 2 seconds. Figures 2 and 4 may illustrate the differences between the respective latencies. In both cases, however, there are almost no marked differences in the respiratory mevements produced. In short, in both cases, by application of a stimulus, there occurred irregular respiratory movements with increased amplitudes, and then apnoea or abnormal respiration, accompanying the movement of the body. Such irregular respiration continued for a while after the pouring of those chemical substances onto the mouth had ceased. Afterwards, it recovered gradually to normal respiration. In most cases there occurred a disappearance of the cleaning reflex or a decrease of its frequency. As stated above, we could not determine in the present experiment that there are marked differences between the stimuli of CO_2 and HCl. Accordingly, we should hesitate to conclude from our experiment dealing with fish that CO_2 stimulates

exclusively the respiratory center.

Apart from the question as to what extent harmful chemicals, are dissolved at any given time in the water in which the fish live, it is beyond doubt that CO_2, or acids, would, to some extent, bear influence upon the behavior of fish. It is therefore, quite reasonable to take into consideration that the defensive conditioned reflex will be very quickly formed in fish while in their natural environment, where they would be free from the danger of such chemical substances. Our result, together with that of Chernova, seems to indicate that there is a possibility of providing a conditioned reflex between dangerous chemicals and various indifferent stimuli, in order to ensure the life of fishes in their variable circumstances. Consequently, it may be emphasized that this matter has a deep bearing upon the fishery industry, especially upon fish farming.

SUMMARY

1) In order to establish a respiratory defensive conditioned reflex in carp, both the solutions of CO_2 and HCl were used as unconditioned stimuli. Light, buzzer and water current onto the lateral line were applied as conditioned stimuli.

2) In combination of CO_2 with either light or buzzer, a respiratory conditioned reflex was stably formed after 2 times of reinforcement. In case of water current, a stable conditioned reflex was hardly obtainable, though a weak conditioned reflex was formed after 2 times of reinforcement as well.

3) In combination of HCl with light, a respiratory conditioned reflex was formed after 2 times of reinforcement, but it requires many more repetitions of reinforcement to establish a stable one.

4) Concerning the speed of formation of respiratory conditioned reflex, it may be said that the temporary connection by means of CO_2 is slightly quicker than that of HCl. But, no marked differences were found in the changes of respiratory movements between both solutions.

5) For the extinction of the respiratory conditioned reflex it required a large number of extinctive stimuli, and in case of HCl it seemed to require many more extinctive stimuli than in the case of CO_2.

6) It is emphasized, that the quick formation of a defensive conditioned reflex by application of harmful chemical substances, such as CO_2 and HCl, when in excessive quantities in the water, has proved to ensure the life of fishes in their variable circumstances.

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Some Remarks in Estimating Natural Mortalities in Population Dynamics of Fish Resources

Ichiro YAMANAKA

1) *Preface*

In the study of population dynamics of fish resources, one of the most difficult works is to separate natural mortality from that caused by fishing. Several methods have been considered to estimate natural mortalities, but it is not saying too much that no definite method has been deviced yet, here the author intends to relate on the significancy of estimating natural mortality, make some remarks on several methods on present use particularly from the standpoint of their efficiencies, and present some opinions how to overcome the difficulties.

2) *Significancy of natural mortality in population analysis*

A caution should be taken that the estimation of natural mortality is important, but it has not any significancy *per se*, it is no more only one of vital statistics in population analysis than survival rate or recruitment.

Sometimes, the value of natural mortality seems a keypoint of the analysis, but sometimes it does not.[1][2]

We must not confuse whether the value of natural mortality is high with that its value has much to do with analysis. Even if that value is high, its fluctuation may not cause any significant difference in other discussions.

After notations of WIDRIG[3], a rate of exploitation u in a given period can be expressed in the form,

$$u = \frac{p}{p+q}\left[1-e^{-i}\right] \quad \cdots\cdots (1)$$

here p, q, and i, show instantaneous fishing, natural, and total mortality coefficients respectively.

The total mortality coefficient $p+q=i$ can be calculated by age compositions, therefore it is more convenient to express the same formulae in the following form in order to deal with the effect of the variation of natural mortality coefficient q upon that of the value of u.

Then $$u - \frac{i-q}{i}\left(1-e^{-i}\right) \quad \cdots\cdots (2)$$

$$\triangle u = \frac{-1}{i}\left(1-e^{-i}\right)\triangle q \quad \cdots\cdots (3)$$

and $$\frac{\triangle u}{u} = -\frac{\triangle q}{q}\left(\frac{q}{p}\right) \quad \cdots\cdots (4)$$

Therefore when the value of i is high, in another saying, the survival rate

is low, the variation of natural mortality coefficients has little to do with estimates of rate of exploitation, and moreover, the relative variances of them are influenced much by those of natural mortality coefficients in cases when the values are much larger than those of fishing mortality coefficients.

Bottom fishes such as SOHACHIGAREI (*Clethenis herzensteini*) or MUSHIGAREI (*Eopsetts girgorjewi*) seem to belong to the former category after the study of trawl fisheries resources carried out by Japan Sea Regional Fisheries Research Laboratory[1], while MAIWASHI[2] (*Sardinops melanostica*), to the latter one.

Tab. 1 Effects of the shift of natural mortality coefficient q upon that of estmated rate of exploitation u.

Sohachigarei (*Cleisthenis herzensteini*) in Japan Sea $i = 1.14$		Mushigarei (*Eopsette grigorjewi*) in Japan Sea $i = 1.07$		Maiwashi (*Sardinops melostica*) in Kyushu $i = 0.56$	
q	u	q	u	q	u
0.20	0.69	0.30	0.70	0.20	0.27
0.30	0.67	0.40	0.66	0.30	0.20
0.40	0.61	0.50	0.61	0.40	0.12
		0.60	0.57		
(1951–54)		(1951–54)		(1952–55)	

As can be seen from these examples the effect of the shift of q upou that of u is not constant but varies case by case.

3) *Precision of estimated natural morality coefficient*

One of the orthodoxical methods estimating natural mortality is the regresion analysis of is against fishing efforts. This can be shown in a simple equation of the form,

$$i = QF + q \quad \cdots\cdots (5)$$

WIDRIG ('54)

here, Q is the instantaneous unit fishing intensity coefficient and F is the amount of the fishing effort.

Two unknown parameters are included in this equation, so if the number of unit period for observed exceeds three, we can solve them by ordinary least square methods. Then the unbiased estimates should be,

$$\hat{q} = \frac{\Sigma i F \Sigma F - \Sigma i \Sigma F^2}{n\Sigma F^2 - (\Sigma F)^2}$$
$$\hat{Q} = \frac{\Sigma F \Sigma i - n\Sigma i F}{n\Sigma F^2 - (\Sigma F)^2} \quad \cdots\cdots (6)$$

here n is the number of unit periods.

By σ_F, σ_i and *cov.* iF, we denote the variance of F and i and their covariance respectively, then we have,

$$\hat{Q} = \frac{Cov.(Fi)}{V(F)} = \frac{\rho(iF)\sigma_F\sigma_i}{\sigma_F^2} = \rho(iF)\frac{\sigma_i}{\sigma_F}, \quad \hat{q} = \frac{\frac{\Sigma F_i}{n}\Sigma F - i\Sigma F^2}{S(F)} \quad \cdots (7)$$

Here ρ (iF) means the correlation coefficient between i and F.

Then the variances of these estimates have the forms,

$$Var.q = \frac{\triangle}{n-2} \times \frac{\Sigma F^2}{n\Sigma F^2 - (\Sigma F)^2} \qquad Var.Q^2 = \frac{\sigma_i^2(1-\rho^2)}{n(n-2)} \frac{n}{\sigma_f^2} \quad \cdots\cdots (8)$$

here $\triangle = \sigma_i^2(1-\rho^2)$

therefore $$Var.q = \frac{\hat{\sigma}_i^2(1-\rho^2)}{n-2} \frac{\Sigma F^2}{\frac{n}{S(F)}} = \frac{\Sigma_i^2(1-\rho^2)}{(n-1)\ (n-2)} (1 + \frac{1}{C_F^2}) \quad \cdots\cdots (9)$$

here $$C_F = \frac{\sigma_F}{F} Var.Q = \frac{\sigma^{i2}(1-\rho^2)}{n-2} \frac{1}{\sigma_F^2} \quad Var.Q/Q^2 = \frac{1}{n-2}\left(\frac{1-\rho^2}{\rho^2}\right) \cdots (10)$$

As these formulae show, i) The accuracies of Q as well as of q are high when there is high positive correlation between F and i, ii) The accuracy of q is high in cases when either the number of the time unit is large or the variance coefficient of fishing effort is large enough. iii) The accuracy of Q also depends upon the value of that correlation coefficient, but the dependency upon the number of unit periods is less important that in the case of q.

Here we considered *Var.* q for q and (var. Q)/Q for Q. It is due to the fact that the value of q is itself of logarithmic form, so its standard deviation means the relative error of its estimates.

Very few fisheries in Japan can afford such data of long period enough to clarify this correlation. For California sardine, the author obtained the values of $C_f = 0.34$, $\sigma_i = 0.65$ and $\rho = 0.63$, pretty high values, by data shown by WIDRIG('51), in this case, $\sigma_f = 0.16$.

But only few fisheries seem to have such high correlations between i and F.

In Japan, the above mentioned SOHACHIGAREI caught by trawl fisheries in the Japan Sea is one example which has data of comparatively long period. This gives results, $n=7$, $S_i=0.34$, $\rho=0.31$ and $C_f=0.12$ the variance of efforts is not so high and the precision of q is rather poor ($q=0.39$ $\sigma_q=1.4$).

In other fishes caught by trawl nets in Japan or MAIWASHI these correlations are rather low, even and negative value sometimes.

Sometimes we deal the decreasing of population within a fishing season, in such cases we cannot increase n beyond a certain limit, for most fisheries the fishing season lasts only for several months, so if we can get the fisheries statistics by month, the value of n cannot exceed six or seven usually, in most cases, as shown in the cases of MAIWASHI[2](1956) this is only three of four.

In addition, the values of is have inevitable sampling errors because most fisheries statistics in Japan is tabulated in weights, so we must convert them into number by dividing them into the average body weight obtaind by measuring. The number of a certain age must be estimated by age determination, so the values of total mortality suffer from many considerable sources originating errors, some of which can be, however, reduced by devicing powerful sampling

methods. But costs limit such improvement of sampling methods practically.

It is considered that in order to increase the value of n catch statistics should be arranged for shorter units, for example for weeks or days, but we can easily suppose that this sacrifies at the same time the precision of each value, and increase the difficulty in arranging statistics.

At the other hand, in cases when we deal annual survival rates by age composition statistics of a long period, we expect to increase the numbeir of n by continuing the survey for a long term, but in this case we cannot always expect that the fundamental hypothesis of constant natural mortality stands constanly.

This paradox occurs similarily also for the variance of fishing efforts. Big variance of efforts makes a high precision of those estimates, but at the same time it means a change of fisheries situations, so in such cases we should rather assume that there must be some change either in environment or social conditions, so the parameters in fundamental equation cannot be constant.

4) *Comparison with DE LURY's methods*

In cases catch per unit effort decreases with the accumulation of catch or efforts, DE LURY's methods[4] are applicable. His original methods do not consider natural mortality, but he mentioned cases in which two or more kinds of gears affect on population, and referred that natural mortality can be dealt as one kind of fisheries which has always a constant effort. Then we have the following form of equation.

$$k_i = log.\ (So/S) = Q\Sigma F_i + nq \quad \cdots\cdots (11)$$

Here S_o and S_i represent the catch per unit at the beginning and the i-th period respectively, while ΣF_i, the accumulated catch up to that period.

$$\frac{k_i}{n} = Q\overline{F}_i + q \quad \cdots\cdots (13)$$

Here $\overline{F}_i$ is the average of accumulated effort, So k_i/n is so called mean accumulated decreasing rate.

By this equation, it is shown that both decreasing rate and number of effort diminish their variances as they are averaged by increasing n and so we cannot expect to increase the correlation between effort amounts and decreasing rates, neither can we expect to improve the precision of estimates by these methods.

5) *Some reflections upon mathematical models*

As mentioned in earlier chapters, we confront an inevitable difficulty in population estimation. Is this due to the defficiency of these fundamental mathematical models? Let us consider this question from another angle of view.

OSHIMA ('54)[5] made an experiment with TENAGAEBI (*Palaemon nipponensis* de Haan) by an aquarium and showed that the estimation of population by

mathematical analysis coincides with the actual size within confidential limits*. In this case, $n=11$, $q=0.2$, $\sigma_q=0.15$ $s_i=053$ $s_F=0.31$ while $\rho=0.31$. In such enclosed area we can expect good results.

It was also shown by the same experiments that catch per unit effort had no significant differences form the linear regression on the actual number of shrimps at that time within the confidential limits. Therefore it seems possible to make catch per unit be proportionated to the population size in controllable experiment in a limitted area.

Another experiment concerns with the following question. We are sometimes confronted with examples of fisheries in which catch per unit effort decrease monotoneously with the ellaps of time. Can we consider this phenomenon is caused by the decreasing of population by fishing alone in such case? Is there no risk for us to make an erroneous conclusion, by computing with catch and effort data, attibuting the decreasing to the effect of fisheries even when the natural mortality occupies the main part of total mortality?

In order to solve these questions, let us try one thought experimement as follows.

Assume an ideal population with natural mortality of 50 % for a unit period, fishing mortaliy being one thousandth per unit gear and the original population size is one million.

Under a shift of the number of efforst between 20 and 100, that is, the fishing mortality lies between 0.1 and 0.02, we can get values of catch per unit effort as follow.

Table 2. Thought experiment on catch and efforts

N	F	C	c/u
100	100	10	1000
40	50	2	400
18	30	0.54	180
8.63	100	0.85	85.6
4.38	70	0.24	33.8
1.45	20	0.029	14.5

By inverse calculation from these data, we can get $e^{-q}=0.52\pm0.02$

These values coincide with the actual ones successfully.

By these considerations, we know that even if the value of natural mortality is high we can separate natural mortality from that of fisheries with good precision when the population is in an ideal condition.

6) *What makes the precision poor in population anaylsis ?*

Equations (9) and (10) show that the values of ρ, the correlaton coefficients between fishing efforts and total mortality have much to do with precisions, and the actual data in our hands show that one of the chief reasons of these poor precisions can be considered to be due to the low correlations among them. This infers a very important fact in population analysis in fisheries, *at least, which we*

* Computed by YAMANAKA

have been studied in Japan. This means that the variation of total mortality caused by the change of efforts does not occupy the main part of it.

It can be supposed that i) the natural mortality which hitherto dealt as constant is, in fact, a variable with a pretty wide range, ii) there are other factors giving influences upon the variation of total mortalities.

If we can find out these factors besides fishing mortality, we can improve the correlation by multiple regression analysis, because multiple correlation is always larger than single correlation.

Biological consideration are required to explain natural mortality and its variation if it exists. But this is beyond this aim of this report.

But one of the factors which give influence upon mortality besides fishing is the change of availability, that is, because of the selectivity of gear or fisheries itself, only one part of stock can be fished, so catch per unit effort does not always represent the magnitude of population size in itself but does it only the magnitude of *avaible stock.* When only one part of total stock is available, mortalities obtained from age composition are not real ones, but are *apparent* ones which contain the relative changes of availablity.

WIDRIG dealt the residues of total mortality coefficients from the linear regression againt the effort numbers as caused by the variation of availability, and he applied this idea to California sardine and calculated relative values of availabilities.

The author calculated with his data and obtained the correlation coefficinet between the relative availability and catch per effort as ca. 0.64, whereas, the change of total mortality and that of availability has positive correlation more than 0.9.

In Japan, many studies have been donc on the relation between hydrography and fisheries conditions, but very few of them are quantitative. Hydrographic conditions seem to affect availability powerfully, so it should be necessary to make study of availability and hydrographic conditions in order to make the quantitative prediction available.

But WIDRIG's method can be applicable only when the change of availability has no autocorrelation and can be dealt as random residues from that regression line. When we deal data year to year for long period like Calfornia sardines this assumption may be available, but when there is a tendency in the change of availability, this method cannot be used. We are confronted with such cases frequently when we deal with data *within* a fishing season, for example, the monthly change of catch per effort within a season; in such analysis we sometimes obtain negative values for either natural or fishing mortalities by these methods, this often can be inferred by the systematic change of availabilities(2). caused by oceanographic or biological changes.

7) *A comment on tagging analysis*

Thus we cannot but be confronted with a grave difficulty in estimating natural mortality. In order to overcome this difficulty, let us consider the alternative methods besides the catch and effort analysis. Does the tagging help to overcome it?

Tagging is used for finding the migration habit as well as for estimating population size, but many difficulties have already been disussed on them: for example, the dropping the tags, the differences of behavior of tagged fish from others, and misfinding of recaptures.

In order to overcome these difficulties, BEVERTON[6] showed the estimating method by obtaining the ratio of two succeeding time units.

Assume the number of release N_o, the length of time unit t, and the sum of natural mortality and thas by tagging X, then we have,

$$\frac{n^{\gamma}}{No} = \frac{QF^{\gamma}+X}{QF^{\gamma}} e^{F\bar{t}+((\gamma-1)X))}\left(1-e^{-(F\gamma+X)}\right) \quad \cdots\cdots(12)$$

then

$$\frac{n^{\gamma}}{N^{\gamma}} = \frac{QF_{\gamma}}{QF_{\gamma}+X}\left(1-e^{-QF\gamma-X}\right) \quad \cdots\cdots(14)$$

Here, N_{γ} is the number of taggs remaining after the γ-th time unit.

His equations is completely equivalent to those which represent the relation between fishing efforts and exploitation ratio so we have a same form of equation as the previous one.[5]

This equation aims to eliminate the abundant death immediately after releasing, and moreover to eliminate the effect of misreports by using the rate between two recaptures, but by these procedure, its form becomes same to that of (5). So we must be troubled by the same difficulties as are related in the Chapter 3).

8) *Scouting survey by fish finders*

YOKOTA et al. ('53)[7] deviced a method estimating fish population by fish finders. Here the research boats with fish finders cruise periodically along the appointed courses, the numbers of shoals are estimated by number of shadows on recording papers, and the magnitude of each shoal by the length, width, and thickness of each image.

If we may assume that the number of shoals thus obtained is proportional to the magnitude of stocks, we can make same equations as in Chapter 3), only by substituing this value for cach per unit effort as an index of stock size. But this method will be applicable only for solving the variation of population size within a fishing season, because by this method we cannot know the age composition of catches unless we sample fishes from these shoals, and moreover, even in such a case, the increase of body weigh caused by growth should be taken

into account.

Theoretically there is no diffierence between the catch and effort analysis and this method from mathematical viewpoint, so the difficulties in population calculation lie in the same points as been discussed in earlier chapters. In this method we can expect to estimate the number of shoals with pretty precision by applying appropriate design of courses. So long as the images on recording papers represent the actual shoals in the ocean, they seem more suitable than catch per efforts as indices of stock size, because they do not rely upon catch statistics. But it is a well known fact that sometimes a dense shoal does not make an apparent image, because the appearance of image are associated with the structure or depths of shoals in the ocean. But these problems would be solved by the proceeding of acoustical and technical studies of fish finders, and moreover, it can be easily supposed that the estimated shoal abundance must have high correlation with actual abundance of fish population, so this method can be expected much improvement for practical use in future.

9) *Natural mortality before recruiting stage.*

Hitherto have been dealt chiefly about the adult fishes which suffer fishing and natural mortality contemporalily, but as has been mentioned in the earlier chapter, natural mortality after commercial stage has not always to do seriously with the result of population analysis. On the other hand, the natural mortalities of some species in their early stage of lives makes crucial effect on their recruitment to comercial adults, only a slight shift of their values making wide fluctuation of year classes originated by this brood.

NISHIMURA ('56) classified the causes of natural mortalities of early stage of lives[8].

It can be suggested that there are three types of recruitments, first, with pretty steady forms like flat fishes, second, with sporadic forms like cod or herrings, and last, of undeterminable form like sardines.

It is an important problem whether there is any association between the number of parent fishes and that of year class originated by it, and no definite conclusion has been obtained[9]. As for Japanese MAIWASHI it is more probable that there is no such relation[10]. In such a case we can say that the natural mortality in early stage determines the abundance of recruitment. Let us adopt NISHIMURA's opinion that the main cause of that natural mortality is the starvation in larval stage, then in order to discuss this relation we must plot the regression of the strength of recruiting year classes against the food abundances (or some merkmal of them) which coexist with sardines. As both larval sardines and their food material seem to make patches in their distribution, so the total abundace of food is not sufficient as a factor determining natural mortality, but we must consider the probability of encounting of fishes to their food. Knowldeges

on patterns of their spacial distribution are necessary to access this problem, and the estimation of the abundance of food which utilized for nursing of larvae cannot but to have pretty amounts of errors. Sorrily the author has no actual data for this compution, but it is clear that long series of time isrequired in order to make regression analys is of this relation, especially considering that both of them are inevitably estimated values with pretty large errors.

10) *Conclusion*

Thus it has been theortically clarified that the population analysis especially concerning natural mortality cannot be expected unless we accumlate data of long series of period. Each data should be improved in their precisions in order to diminish the scattering of points from the esimated regression lines. And we must not rely upon only one method, but should compare the results obtained by methods several each other.

To study biological mechanism of each cause of natural mortality for example, predation, starvation, cannibalism and so one is effective, but it is not sufficient for our aim, because we must not forget that every factor influences upon the variation of population stochastically but not deterministically. So we must test the results stasistically which had been obtained by biological experiments.

Population analysis must be steadily carried out with endurances.

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イカによるイワシ類の食害量

伊　東　祐　方

How many young sardines damaged by cuttle-fishes ?

By

Sukekata ITO

It has been long recognized that sardines including anchovies are predated by cuttle-fishes and other animals (fishes, whales, sea-birds, etc.). But, no quantitative treatment regarding this problem has been ever made. The writer has examined the published data to estimate the quantity of young sardines predated by cuttle-fishes for a given period in adjacent waters of Hokkaido. The method is as follows.

If we ever know the amount of maintenance protein, growth rate, food composition, annual fishing rate, annual total catch and so on of cuttle-fishes for a certain period, we can easily calculate the minimum protein requirement of a cuttle-fish, quantity of sardines predated by a cuttle-fish, magnitude of cuttle-fish population, and then the quantity of young sardines destroyed by this decapod mullusk population annually.

It has been thus cleared up that the quantity may be larger than annual yield of cuttle-fishes caught by fishing boats and is hardly less than sardine catch in Hokkaido sea area. Sardines are also exposed to predation by various kind of animals but besides cuttle-fishes. In addition, when we make the same estimation all over the waters surrounding the Japan Islands, the total mass of young sardines destroyed annually by cuttle-fishes and other aquatic animals would be identified to be enormously large.

Accordingly, we must pay serious attention to the magnitude of predators of sardines, when we study on the sardine resource problem.

はしがき

イワシ類を食害するものには多くの魚類のほか，イカ類，イルカ，クジラ，海鳥などがあり，魚類ではいわゆる回游性魚類だけでなく，底魚と称されているものも含まれている。

堀田，小川（'55）は東北，伊豆諸島及び九州西岸海域で漁獲されるカツオの餌料としてイワシ類とくにカタクチイワシが重要であると報告し，前田ほか（'55）は山口県沖合のサバの餌料を調査した結果，餌料生物として魚類が最も重要でとくにカタクチイワシ，マイワシが量的にも多く，5～6月に漁獲されたものでは重量組成で67～100%を占めていると報告している。なお，スルメイカの餌料としてイワシ類が重要であ

るとの報告は後述するように極めて多い。即ち，イワシ類を食害するものは極めて多く，資源解析に際してその食害量に多大の関心がもたれている所以である。

そこで，既往の資料に基いて，イカ類とくにスルメイカによつて捕食されるイワシ類の量について推定する試みを行つたので報告する。

推定の方法

動物が生命を維持するためには必ず一定量以上の蛋白質を摂取する必要があり，その最低量は最低保持蛋白質量といわれ，それ以上の体の増重に用いられる蛋白質量は増生蛋白質量といわれている。

ある限られた期間のスルメイカの個体当りの最低保持蛋白質量及び増重量がわかれば，ある仮定のもとに単位期間当り最低摂取蛋白質量が推定され，また，その期間のスルメイカ餌料のうち，イワシ類の占める比率が判れば，単位期間当りのイワシ類を摂取する量が求められる。さらに，スルメイカの年漁獲率，漁獲量が判明すれば近似値的のスルメイカの資源量が推定される。これらから，ある期間のスルメイカによつて食害されるイワシ類の量が求められることになる。

このような考えにたつて，スルメイカがイワシ類を食害する量を推定したものである。もちろん，この推定に当つては，充分な資料がないため，大胆な仮定によつて推論したもので，得られた数値そのものにはまだ問題があることを附記しておく。

スルメイカの成長及び寿命

北水試旬報 ('28) によれば，北海道海域で漁獲されたスルメイカについては，7月以降の体重は直線的に増加し，1カ月に約32g増重するといわれ，伊藤 ('52) は佐渡近海産のものでは，体重は直線的に増加し，1カ月に約24g増重し，寿命は1年半程度と推定している。川名 ('53) は北海道近海産のものでは約 20g増重し，漁獲物中の大きいものは胴長約 25cm，体重は 350g 内外で，寿命は約1カ年と推定し，田内 ('41) は漁獲物の体重組成から寿命を数年と推定した。

これらから，スルメイカの体重の増加は直線的で1カ月の増重量は約 20g 以上で，寿命は約1カ年程度とみられる。

今回は資料の関係上，北海道のスルメイカについて論ずることにする。

北海道のスルメイカの漁期は5月から翌年の1月で盛漁期は7～12月であり，6月には体重 100g 前後，12月には300g以上のものが漁獲される。

ここでは6月から翌年1月の8カ月に限り取扱い，その期間に体重 100g のものが 300g に増加する。即ち，1カ月の増重量を 25g とし，また寿命は約1カ年と仮定し推論を進める。

スルメイカの最低保持蛋白質量及び増生蛋白質量

スルメイカの最低保持蛋白質量に関する報告は全くない。

MOORE, B., EDIE, E. S. and WHITLEY, E. ('14) はロブスター，タラ，タコ (体重 370g) について飢餓状態においた時の呼吸量から推定して，タコ，タラの最低保持に要する1日当り蛋白質量は生肉に換算すれば 3g に相当すると報告している。生肉の粗蛋白質量を 2.1% と仮定すると粗蛋白質量は 600 mg となる。

右田，花岡，都筑 ('57) は当才魚のコイについて飢餓時における全排泄物中の窒素から計算して，水温22～24°Cでは体重 100g について，1日当り約30mgの窒素即ち 188mg の粗蛋白質量が必要であると報告している。

ここでは，最低保持蛋白量が体重に比例し，スルメイカの代謝がコイ，タコのそれと等しいとすれば，スルメイカの1日当り最低保持蛋白質量は体重 100g につき MOORE らのえた値を用いると 162mg，右田らのえた値を用いると188mgとなる。両者の値には多少の相違はあるがその差は著しくないので，両者の中間値をとり175mgをスルメイカの体重100g当りの1日の最低保持蛋白質量とする。即ち1カ月では 5.25g となる。

次に，スルメイカの肉の粗蛋白質量は17%であるから（'56），スルメイカが1カ月に25g増重するに要する増生蛋白質量は4.25gとなる。すると，体重100gのスルメイカが8カ月後300gに成長するに要する最低摂取蛋白質量（最低保持蛋白質量＋増生蛋白質量）は118gとなる。

この値は最低摂取蛋白量であつて運動に要するカロリーは考慮にいれていないし，また消化率なども考慮にいれていないから，実際の摂取量は遙かに多いものでなければならない。

右田，花岡，都筑（'38）はコイの場合，餌料，水温その他によつて異なるが日間投餌量は体重の3%を与えた場合が最も経済的に有効であると報告し，OKUL('41)，SUSKKINA('42)，IVLEV ('38)，MAISKY('39)は時期，水温，餌料によつて異なるが数種の流嘴魚の場合，日間摂餌量は体重の5～11%程度であると報告している。

もし，スルメイカの日間摂餌量を体重の5%とすると，体重100gのスルメイカの日間摂餌量は5gとなる。いま餌料の粗蛋白質量を15%とすると，日間摂餌蛋白質量は0.75g（月当り22g）となり，今回求めた月間最低摂餌蛋白質量9.5gに比して約2倍となつている。これらからも今回求めた値は実際より低いことが窺われる。

スルメイカの餌料

スルメイカの形態上の特質をみると，(1) 口器が発達し，角質の顎をもつている。 (2) 吸盤をもつ強力な腕をもつている。 (3) 視覚が発達している。 (4) 体に紡錘型で鰭をもち，噴出式の敏速の運動をすることができる。 (5) 胃はかなり大きく長楕円形で強靱な筋肉をもち，腸は比較的短い。これらのことから運動は敏速で，肉食性で，且つ大型のものをも餌としてとりうることが想像される。

SASAKI ('21) は北海道近海で漁獲されたスルメイカの胃内容物を調査し，小型のものはほとんどが浮游性甲殻類を摂つているが，漁獲対象となる大型のものでは餌料の約70%が小型魚類（サバ，マイワシ，ウルメイワシ，カタクチイワシ），20%は共喰，10%は浮游性甲殻類であつたと報告している，川名 ('53) は餌としてはイワシ類，小甲殻類が重要であるとし，添田 ('56) は北海道の春期～夏期の北上回游群の餌は魚類（イワシ類，サバなど），同族（共喰），浮游性甲殻類（*Mysis sp, Themisto sp.*）の3類に大別でき，それらの組成は採集時の環境によつて異なり変異が大きい。また秋期の盛漁期には共食現象が常にみられ，漁場海域でイワシ類が漁獲される時期及びその前後には魚類の出現率が大きく，漁期をずれると浮游性甲殻類が多く出現すると報告している。北海道水産試験場旬報（21，23，25，34，48，62，63，105号）によれば北海道の夏期—冬期のスルメイカの餌料としては魚類（イワシ類，サバ，ニシン）が最も重要であるとの記載が多く，そのほか浮游性甲殻類，同族，頭足類などが餌料となつている。なお，121号 ('31) によれば7～12月に亘つての44回調査では，空胃の場合12回，イワシ18回（40%），イワシ，イサザ混食の場合が7回（15.6%），イサザ5回，イカ2回で，イワシを食餌している割合が極めて高いとの結果をえている。安井 ('55) は1953～'54年の八戸沖のスルメイカの胃内容物の調査結果では，浮游性甲殻類が最も多く，ついで共喰，魚類の順で，魚類の出現率は1953年5.5%，1954年11.7%で，魚類ではカタクチイワシ，イカナゴがみられたと報告している。

以上から餌料種の水平垂直的分布，密度が時期，海域及び年により相当変動があることは予想されるが北海道近海のスルメイカの餌料としてはイワシ類，その他魚類，甲殻類，同族などが主要餌料であるといえる，とくに，大正中期～昭和初期にはイワシ類が相当高い比率を占めていたことは予想されるが，近年では同海域のイワシ類資源の減少その他によつて餌としての重要性は減じたようである。しかし，近年といえどもイワシ類の漁期及びその前後には相当量のイワシ類がスルメイカによつて捕食されていることは確かであろう

スルメイカ個体当りのイワシ類食害量

スルメイカの餌の量的組成についての報告は2，3あるにしても充分信頼しうるものはないので，先に求

めた8カ月間に摂取しなければならない最低摂取蛋白質量（118 g）のうち，イワシ類に依存する割合（S）を0.05，0.10，0.15，0.20とした場合について検討を進める。

即ちSを0.05，0.10，0.15，0.20とした場合の個体当りイワシ類から摂取される蛋白質量はそれぞれ，5.9，11.8，177，23.6 g となる。西川，林（'36）によれば北海道産小羽イワシの肉の粗蛋白量は17～18%といわれる今回は17.5%としてイワシの生肉に換算すると，それぞれ33.7，67.3，101.0，134.6 g となる。

次に，大谷（'49）によれば小羽イワシの可食部は56～57.5%といわれるから，魚体の58%が生肉で占められているとして，イワシの重量に換算すると，それぞれ，58.0，116.1，174.0，232.1gに相当することになる。

さらに，このような検討を行う場合にはイワシ肉の消化率を考えなければならないが，スルメイカがイワシを摂餌した場合については研究されたものがない。右田，花岡，都筑はコイの場合，餌の種類，水温その他の条件によつて異なるがコイ肉の場合では89%であつたと報告し，ARNOLDI et FORTUNATOVA（'37）は海産魚数種についての実験から消化率は多くの場合80～90%であると報告している。

今回は消化率を90%とすると，Sを0.05，0.10，0.15，0.20にとつた場合の摂取すべきイワシの重量はそれぞれ64g（0.017〆），129（0.034），193（0.052），258（0.069）となる。

スルメイカの漁獲率

田内（'41）は標識放流の再捕結果，及び年級別の組成などから，スルメイカの年漁獲率は1.11，生残率は0.67と報告している。この推定に当つてはイカの寿命を数カ年とみているので多少問題があろう。花村（'55）は北海道海域での1928～1952年の標識放流結果を検討して，再捕率は決して考察に値しないほど低いものではないが，1940～1950年の間に漁獲努力数（総数で約2倍），漁獲量が3～5倍と過去に比して増加したにも拘らず，標識イカの放流後の時間的経過に伴う再捕の傾向は過去と殆んど変化がないことから，漁業の変化や漁獲量の変化が再捕される経過に対して何等の変化をも及ぼしていないとし，また，多年生のものとは考えられないので，その漁況の変異は海況による直接漁場構成の変化，その他漁業上の問題も関係してこようが，主として発生年級群の強弱に左右されるものと推定している。

いずれにしても，スルメイカの漁獲率についてはまだ明かにされていないが，イワシ，ブリ，タラなどの魚より低いのではないかと推定される。今回はスルメイカの年漁獲率（F）を0.10，0.15，0.20，0.25，0.30とした場合について検討する。

北海道近海のスルメイカによるイワシ類の食害量

北海道近海の体重100gのスルメイカが8カ月後に[illegible]gに成長すると仮定した場合，その期間に摂取しなければならない最低摂取蛋白質量（118g）のうち，イワシ類を摂取することによつて占める比率がSのときのイワシの重量をAとし，スルメイカの年漁獲量をY，年漁獲率をF，漁獲物の一尾当りの平均重量をWとすれば，イワシ食害量（X）は近似的に次式で求めることができる。

$$X = KY$$

但し　$K = \dfrac{A}{F \times W}$

W……0.053〆

A……$S = 0.05,\ 0.10,\ 0.15,\ 0.20$のとき

$A = 0.017,\ 0.034,\ 0.052,\ 0.069$〆

F……0.10，0.15，0.20，0.25，0.30

Y……〆

S及びFに種々の値をとつた場合のKの値は次表で示される。

即ちKの値はこれらの種々の仮定値を小さくした場合でも 1.1を示し，イカによる食害量が決して僅少でないことを示している。

S(A~) \ F	0.10	0.15	0.20	0.25	0.30
0.05 (0.017)	3.2	2.1	1.6	1.3	1.1
0.10 (0.034)	6.4	4.3	3.2	2.5	2.1
0.15 (0.052)	9.8	6.6	4.9	3.9	3.3
0.20 (0.069)	13.0	8.7	6.5	5.2	4.3

イワシ類及びイカ類の漁獲量

北海道のイカ類，イワシ類（3カ年移動平均）及び全国のイワシ類漁獲量を Fig. 1 に示した。北海道イ

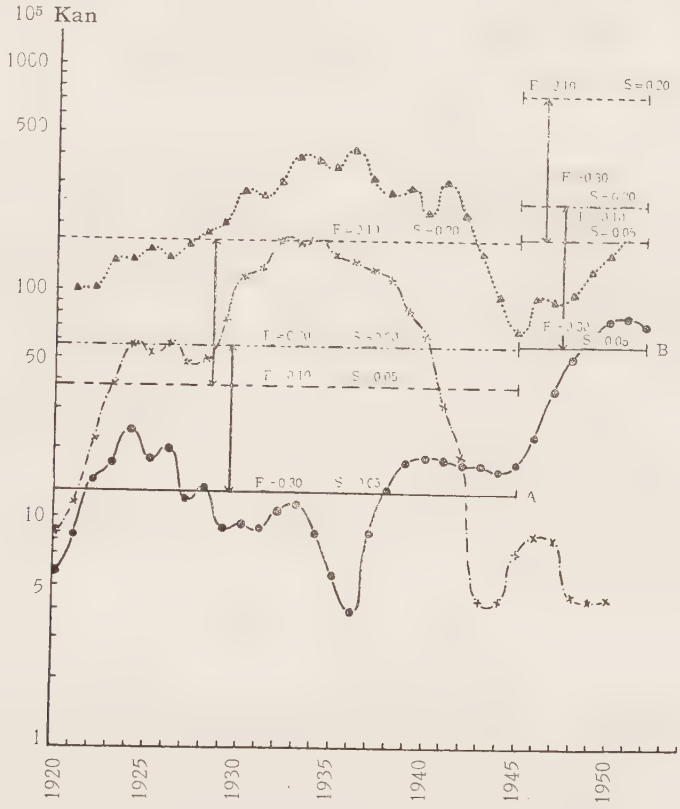

Fig. 1 Showing the annual yield of sardines and cuttle-fishes in Hokkaido and throughout Japan. Also is indicated the quantity of young sardines predated by cuttle-fishes when S and F are changed in various values.

……▲…… Annual yield of sardines throughout Japan.
—·—×—·— 〃 〃 in Hokkaido. (moving average for successive three years)
——●—— 〃 〃 cuttle-fishes. (〃 〃)

F……Annual fishing mortality rate.
S……Proportional contribution of the sardine meat to the minimum food requirement of a cuttle-fish during the period the latter growths from 100 gr to 300 gr.
A……Mean annual yield of cuttle-fishes in Hokkaido from 1920 to 1945.
B…… 〃 〃 〃 〃 from 1946 to 1952.

カ類の漁獲量は1920年頃より順次増加し，1924年頃には2千万貫をこした。その後減少し，1936年頃を最低としてその後再び上昇し，1939～'41年頃まで1千7百万貫前後を示した。その後急激に増加し，1950年頃には8千万貫に達した。

一方，イワシ類の漁獲量は1920年頃から順次上昇し，1932～'34年頃を最高としてその後急激に減少し，1942年頃から後は1千万貫に達しない現状である。

イカ類（スルメイカが99%以上を占める），イワシ類（1920～1945年頃まではマイワシが主体を占めていたがその後はカタクチイワシが増加し，近年では50～90%がカタクチイワシである。）とも漁獲変動が大きく，かつ，その増減が両種では対象的であるのが注目される。

ここでは1920～45年のイカ類の平均漁獲量を1千3百万貫，1946～52年のそれを5千8百万貫として，$F = 0.10, 0.30$，$S = 0.05, 0.20$ とおいたときの，イワシ類のスルメイカによる食害量の限界を Fig. 1 に示した。これとイワシ類漁獲量（マイワシの場合は小羽～大羽を含んでいるのでスルメイカの食害の対象となると推定される小，中羽イワシはこれより少ない）と比較してみると，イワシ漁獲量に比較して食害されるイワシ類の量は決して問題にならぬほど小さいものでないことが想像される。

考　　察

以上の推論は極めて不充分の資料に加えて大胆な仮定のもとに行つたものであり，数値そのものについては多くの問題があろう。更に，捕食生物と被食生物との関係は両者の水平的，垂直的な分布及び密度，さらに生理生態などの問題も交絡し，年々大きな変異が予想されるから，このような純単な推論には問題が多い。しかし，この計算においては推論の途中で用いた数値に多少の問題があろうとも，いずれも低目にとつてあるので実際には求められた数値より大きくなるものと思われる。

また，今回はスルメイカの漁獲の大部分を占める北海道に例をとつて述べたが，他海域のスルメイカの漁期，漁場と小，中羽イワシのそれらと一致する場合が多く，スルメイカの胃中にイワシ類の存在の認められたとの記載もあり，且又，既述したように，イワシ類を捕食する動物の種類及びその量は極めて多いのであるから，それらによる食害量は決して軽視すべき問題ではないことを強調するとともに，今後充分信頼のおける資料によつてさらに検討したい。

終りに臨み，終始御助言を賜つた東海区水産研究所川名博士，日本海区水産研究所野口栄三郎，加藤源治，西村三郎の諸氏に厚く御礼を申し上げる。

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On some plankton animals occurring in spring off Wajima, Noto Peninsula, Japan Sea, with special reference to their vertical distribution

By Saburo NISHIMURA

Abstract

Plankton collectings by pumping method were made out of seven different water depths: 0.2, 2, 5, 10, 20, 30 and 50 m., yielding samples comprizing both cold-water and warm-water plankters. Brief comments were given to respective species with special respect to their vertical distribution. A relatively discontinuous layer in vertical distribution of many of the discussed animals appeared existing in the neighbourhood of the 20 to 30 m. depth. Cold-water species including *Metridia lucens*, *Calanus plumchrus*, *Parathemisto oblivia*, *Aglantha digitale* and the like occupied principally waters below this layer, whilst sardine eggs were markedly abundant above it. Sardine prolarvae, early copepodite larvae of *Calanus helgolandicus* and *C. tenuicornis* were common in and around this layer. Considerations were made on the nature of this discontinuous layer, suggesting possible causes for the midwater abundance of sardine prolarvae and larval Calanus.

Introduction

Plankton collectings by pumping method were carried out with the aim of investigating the vertical distribution of some important plankton organisms, especially that of sardine eggs and larvae, in the sea adjacent to Wajima, Noto Peninsula, Japan Sea, in the spring of 1955.

Each 90 litres of sea water was taken by an ordinary hand pump out of seven different depths, *viz.*, 0.2, 2, 5, 10, 20, 30, and 50 metres, then filtered through a net made of grit gauze 196 meshes per inch, thus plankton samples obtained for laboratory analysis. On filtrating sea water from the respective depths, a definite volume (ca. 45 *l*) equivalent to the capacity of the hose as well as the pump was previously drained away. It took about 30–40 minutes to complete a series of samplings from the above-mentioned seven depths, and one to three series were made in each experiment.

The station where each experiment was carried out is close to one another (37°28′ N, 136°56′ E), the water depth being 80 m. and its neighbourhood.

Some planktologically important species were picked out of these samples under a binocular microscope and their number enumerated. The results are

shown in the appended table.

Comments on respective organisms

Under are given brief comments on respective plankton animals listed in the table, with special reference to their vertical distribution.

(1) Sardine egg

Sardine eggs are abundant in the surface and decrease gradually with increasing depth. Below the 50 meter depth they are supposed to be only sparsely distributed.

This general tendency of distribution, which is in good accord with the conclusion obtained by SILLIMAN (1943) who worked on the vertical distribution of the California sardine egg, is, however, sometimes disturbed and as results is met with such abnormal, as is considered so, distribution as observed on May 10, 20.33–21.04, when the eggs were most abundant in the intermediate depth and fell down both upwards and downwards, and such as observed on May 21, 16.20–16.48, when the eggs were somewhat uniformly dispersed throughout the depths.

Since the sardine eggs have a specific gravity slightly smaller than that of sea water, they float gradually up to the surface and accumulate there resulting in the above-mentioned general pattern of distribution, when the sea is tranquil with no prominent vertical motion or mixing of water prevailing. In case, however, there are vigorous eddy turbulences or vertical movements, *e.g.*, thermal convection and sinking in the convergence, the eggs would be easily stirred and transported in opposition to buoyancy resulting in various (abnormal) patterns of distribution according to the type of water movement. This is because the differnce in specific gravity between the egg and the sea water is so small and that the egg has a property to change its specific gravity along with the variation in that of the ambient water, always keeping it in contiguity to that of the latter.*

Results from the vertical and the horizontal nettings carried out simultaneously with pumpings have revealed the presence of difference in the pattern of

* The sardine egg has a very large perivitelline space which occupies adout 85 % of the total volume. This space is filled with sea water as well as a certain colloidal substance; the latter is, however, considered to be of so small amount as to enable us to assume that the space be entirely filled with sea water only. In addition, the egg membrane is quite permeable to sea water, the free and unceasing exchange of which is established between the inside and the outside of the membrane. The consequence upon the abovementioned is that when the surrounding water undergoes any change in specific gravity, readily occurs in the sardine egg a corresponding change 0.85 time as large in magnitude. Thus we are led to the understanding that the sardine egg has a tendency to be conservative, non-conservative as it is, in a water block and consequently that in case the water block is making vertical movement or mixing, the egg would be transported quite easily together with the ambient waters.

vertical distribution at times to be observed between different developmental stages of the egg. Detailed discussion on this problem, however, is to be reserved for future papers.

(2) Sardine prolarva

Sardine prolarvae are most common in the intermediate depth, *viz.*, in the 10-30 meter layer. Abundant distribution in the surface, which is the case with the egg, has not been noticed. That is to say, the prolarva shows a different pattern of vertical distribution from its antecedent. Similarity was observed on the California sardine eggs and larvae (AHLSTROM, 1948).

This discrepancy in vertical distribution is supposed due to the possible subsurface hatching out of larvae as well as to their superiority in magnitude of specific gravity to their antecedents. This conjecture may be corroborated first by the observation that richer portion of the eggs immediately before hatching are collected in the main from subsurface waters rather than from the surface, and secondly by another observation upon the behaviour of the egg and the prolarva contained in a jar, the former slowly floating up to the surface, while the latter rapidly sinking down to the bottom. Consulting the latter observation and taking into account as well the prominent adaptation to flotation in prolarval morphology, *e.g.*, the long and slender body axis, the broad marginal fin and so on, is considered the prolarva to be fairly larger than sea water in specific gravity.

The limitedness to principally 10 to 30 m. layer in vertical distribution may be partly maintained through the gravitational sinking intermitted by active but not lasting swimming up of the animals, as is easily watched on the captives in a containing jar.

(3) *Etrumeus micropus* egg

None of this fish egg was collected on April 22, which is interpreted as no spawning was yet taking place. In every experiment since May 10-11, eggs were obtained from various depths by small numbers, suggesting anyhow dispersed distribution. On May 10-11, however, they were collected only from the middle layer and deeper. This pattern of vertical distribution is in noticeable contrast against that of the sardine egg.

(4) *Metridia lucens, Calanus plumchrus* & *Parathemisto oblivia*

These cold-water planktonic crustaceans were caught only on April 22-23 and since then was sampled none at all.

The copepodite larva of *Metridia lucens* was collected only from the 50 m. depth during daytime and in the evening, but at midnight it was obtained from the surface. This may suggest the vertical migration of this species, which has been reported by many authors including CLARKE (1933, 1934), MOTODA & ANRAKU (1951, 1952). The present writer also has experienced during the

cruises across the Bay of Toyama that this copepod migrates up to the sea surface about at midnight and emits strong light as disturbed by bow waves of the sailing vessel.

Calanus plumchrus copepodite larvae (stage V, 4; stage IV, 3; stage III, 2; stage II, 2) were, on the other hand, collected from 30 and 50 meter layers throughout the experiment.

Parathemisto oblivia,* an amphipod widely populated in the Japan Sea, showed an apparent vertical migration, since it was obtained from the 30–50 m. depth in the daytime but from the intermediate to surface layer at night. The migratory habit of this species has been also described by MOTODA & ANRAKU (1954).

All the specimens of *Metridia lucens*, *Calanus plumchrus* and *Parathemisto oblivia* sampled in this experiment were small immature individuals. These species are distinguished representatives of the Japan Sea deep water plankton as reported by many investigators (FURUHASHI 1953; YAMAZI, 1953; *etc.*) and are estimated to inhabit the cold deep waters in great quantities including the adult forms. Immature individuals, however, can be obtained from relatively small depth like in the present case. MOTODA & ANRAKU (1954) have reported that individuals of large size of *Metridia lucens* and *Calanus cristatus* are distributed in greater depth and that only small-sized ones are obtained from shallower depth, while FURUHASHI (1953) has informed that *Parathemisto oblivia* collected from shallow layer is of immature stage and large mature specimens are obtained from greater depth. Similar nature in *Calanus plumchrus* is widely known (MOTODA, 1944; *etc.*).

In the May 10–11 and the following experiments, not an individual of these species occurred. This complete disappearance from samplings would be explained by taking into account the raise in water temperature. Below is shown the mean temperture on respective experiments.

Depth (m)	Mean water temperature (deg. in C.)			
	April 22 (6 obs.)	May 10–11 (6 obs.)	May 15 (6 obs.)	May 21 (4 obs.)
0	12.08	15.93	16.12	17.18
10	11.71	15.13	15.97	16.60
25	11.54	13.88	15.45	16.46
50	11.21	13.28	13.57	14.87
75	10.69	12.71	12.98	13.74

It can be seen that the water temperature at the 50–75 m. depth on May 10–11 had been raised by some two degrees as compared with that on the preceding

* Though there is left some question for identification of this amphipod, the writer tentatively followed the customary way.

experiment. FURUHASHI (1953) has proposed to take 11°C as the upper thermal limit in the distribution of cold-water plankton animals in the Japan Sea. With the fact into consideration that the specimens collected in the present experiment were all immature and small-sized individuals which were possibly regarded as fitted to the temperature a little higher or as of more eurythermal nature than adult forms, is clearly understood by following FURUHASHI's view the disappearance or the diminution in distributional density of the above-named cold-water zooplankters in the observed sea area from the May 10 - 11 experiment onwards.

(5) *Limacina helicina*

This pteropod mollusk was abundantly found in and below the 20 - 30 meter layer in every sampling except in May 15, 16.29 - 16.53, where it was obtained in a considerable number from both the surface and the 50 meter depth.

This tiny planktonic gastropod is one of the cold-water elements as stated by KOKUBO (1948), FURUHASHI (1952) and many others. If the distribution of this species were completely subject only to the water temperature, it would be possible to refer its midwater to deep layer abundance to its cold-loving nature. This is not, however, the case in actual, since on April 22 - 23, when the temperature was low throughout the depths, it was markedly abundant below the 20 meter depth with scanty appearance in the upper layers. Consulting the present datum, the vertically migrating habit of this species, if any, is not observed.

The above-given lines may hint that the distribution of this zooplankter is not completely controlled by temperature but is also affected by some factors else, one of which would appear to be water mass distribution in the sea.

Alike to other cold-water species, the bulk of the sampled specimens belonged to small size category.

(6) *Aglantha digitale*

This medusa, another important member of the cold-water plankton, was abundant in and below the 20 - 30 meter layer with one exception of sampling made in May 11, 05.00 - 05.40, when it was distributed almost evenly from surface to 30 meters.

Like other cold-water plankton animals, only small-sized medusae were collected. The large individuals can be caught from deep waters in the offing.

(7) *Euphausia pacifica*

Larvae (Calyptopis stage) and youngs (Furcilia—Cyrtopia stage) were sampled rather in great quantities on April 22 - 23, after then, however, only poorly. Below are given the sums of specimens obtained in respective sampling series.

It can be seen from the table that the samplings made at night contained more individuals than those made in the daytime or in the morning, further that the number of specimens obtained in the sampling made at about the same time at night remarkably decreased with the progress of season.

April	22 – 23,*	19.27 – 20.04	50
	〃 ,	23.28 – 00.11	63
May	10 – 11,	20.33 – 21.04	more than 12**
	〃 ,	05.00 – 05.40	2
May	15,	12.30 – 13.08	1
	〃 ,	16.29 – 16.53	0
	〃 ,	[illegible]	2
May	21,	16.20 – 16.48	0

As NAKAI (1942), UDA (1952) and other authors have decribed, this euphausiid crustacean inhabits the Japan Sea very abundantly and makes an outbursting propagation in the spring. In the neighboring waters of Waiima, too, not only the larvae of this crustacean species are caught very commonly by plankton netting but also a large amount of the adult forms are occasionally obtained by surface towing made at night.

The above-mentioned decrease in number of sampled larvae and youngs with the progress of season may be due either to the termination of spring propagation or to the dispersal of the population towards the offing and deep in accompany with the raise in temperature in littoral waters. Similarity is delineated by MATSUE & KOMAKI (1954), who observed in the Goto-Izu region, that in the beginning the patches of euphausiid larvae and youngs were commonly found in the littoral waters, but from March on, as was especially distinguished in the Izu region, their distribution was diminished in extent and shifted north, *i.e.*, towards the offing.

It is well known that most euphausiid species have a marked habit to practise vertical migration (II, 1947; NAKAI *et al.*, 1953; *etc.*) and is also mentioned by MOTODA & ANRAKU (1954) that the young of *Euphausia pacifica* as well acts the same behabiour. On the samples obtained April 22 – 23, this migratory habit is clearly observed in the youngs, as they were caught in a considerable number from the 0.2 – 5 meter layer at midnight after aggregation in the 10 – 30 meter layer in the evening. In the daytime their inhabiting depth might be somewhat greater. Concerning the larvae, on the other hand, this habit is not clear, their core of distribution lying at about the 20 meter depth all day long with possible dispersion at night.

(8) *Calanus helgolandicus*

Greater part of the sampled specimens was occupied by copepodite larvae. They were most abundant in the intermediate layer with 30 m. depth as core.

* The series: April 22 – 23, 15.45 – 16.48 lacks two samples of 2 and 10 meter depths, the rest five samples giving sum of 9 specimens, so this series was omitted from tabulation.

** This series lacks 0.2 meter depth sample.

This tendency is particularly apparent in copepodite stages I—III. As for the stage V and the adult forms, on the other hand, a distinct tendency in vertical distribution was not detected, as they were obtained from various depths by small numbers. This may be due to the complexity caused by their diurnal migration and possibly in part due to their dodging movement. Copepodite stage IV appears to be of intermediate nature between the above two categories as concerns vertical distribution.

This copepod is one of the temperate elements and is reported by MOTODA & ANRAKU (1954) to be distributed mainly upper of 150 m. depth. The present study, however, has shown that this copepod species is not the surface plankter in the strict sense, but is distributed, more distinguished as is in the case of early copepodite stages, commonly at some distance below the surface.

The spawning of the Calanus takes place at night near the surface and the spawned eggs begin to sink slowly as soon as it has been laid (MARSHALL & ORR, 1955) so that the hatching out of nauplius larvae and later development are to ensue in middle to deep waters. By paying respect to the foregoing is understood clealy the lack in surface waters of early copepodite larvae, which may be, as seen from the present datum, not yet equipped with the habit or capacity of performing vertical migration.

(9) *Calanus tenuicornis*

Nearly all specimens were copepodite larvae; and the bulk of them were obtained from the layers deeper than 20 meters. Three individuals taken from waters not deeper than 10 m. throughout all the samplings, which were obtained by night pumpings made on April 22, were composed of 2 adult females and 1 stage V, whereas all copepodite larvae younger than stage V were collected from waters 20 meters and deeper.

This copepod has been reported on one hand as a tropical and subtropical species (MORI, 1937) or a warm water species (YAMAZI, 1953; MOTODA & ANRAKU, 1954), and to be distributed in the main in the upper layers shallower than 100–150 m. in the central and northern Japan Sea, but, on the other, TANAKA (1956) has described as a deep water form from the Izu region in the Pacific Ocean. According to the present research, the copepodite larvae are mostly found occupying the layers some distance below the surface as was observed in the larvae of *Calanus helgolandicus.*

(10) *Muggiaea atlantica*

This siphonophoran medusa was dispersed throughout the depths day and night, but was sampled in many specimens from the midwater: 10 to 30 m. on May 15 and 21.

Discussion

Taking a general view of what has been mentioned, it may be recognized that a discontinuous or singular layer, naturally in a relative sense, for the vertical distribution of many of the discussed plankton animals, existed in the neighbourhood of the 20 to 30 m. depth. The cold-water plankton animals including *Metridia lucens*, *Calanus plumchrus*, *Parathemisto oblivia*, *Aglantha digitale* and the like were in the main distributed below this layer, the copepodite larvae of *Calanus helgolandicus* as well as *C. tenuicornis*, sardine prolarvae, and possibly *Muggiaea atlantica* with *Etrumeus micropus* eggs, both of which though showed a somewhat dispersed distribution, were common in the vicinity of it, and lastly sardine eggs were markedly abundant above it.

Consulting the informations by previous authors on the general hydrography of the Japan Sea leads to the understanding of this layer as a boundary or transitional layer between the surface water and the core water of Tsushima Warm Current. The former is warmer, less saline and consequently smaller in both density and molecular viscosity than the latter, so the sinking of plankton organisms may be somewhat retarded when entering into waters beneath the boundary layer. Furthermore, vertical diffusivity is, as is well known, reduced at the junction of water masses of different density, making possible the compaction of the individuals that are constantly sinking from waters above. Thus a consequent accumulation of plankters may occur in the vicinity of the above-mentioned boundary layer.

This will apply not only to the sinking forms such as sardine prolarvae, copepod eggs and early-stage larvae, but no doubt also to most of phytoplankters which are besides accelerated to concentrate there as influenced by the deleterious effect of strong sunlight near the surface. It is common to observe supersaturation of oxygen in standardized expression in waters some distance, say, 20 to 30 m., below the surface in and around the areas surveyed, and this may no doubt be due to photosynthetic activity of flourishing phytoplankton population in those layers. Intermediate-depth abundance in some of the zooplankters such as early copepodite larvae of the Calanus which depend largely on phytoplankton as their principal energy source may be, partly at least, attributed to this rich occurrence of phytoplankton in the midwater layer.

Acknowledgements

The writer expresses his hearty thanks to Mr. Sukekata ITO of the Japan Sea Regional Fisheries Research Laboratory and to his associates on the staff for their encouragements bestowed to him throughout the study. His gratitudes are

also due to Mr. Ichisaburo TSUNA, Captain, and to the gentlemen of the research vessel "Asahi-Maru II" for their kind help in the laboricus and time-consuming work of collecting the samples on board.

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Appended table. Number of some plankton animals contained in respective 90 litres of sea water pumped from seven different depths.

Plankton organisms	April 22 – 23																			May 10 – 11															
	15.45 – 16.48 hrs							19.27 – 20.04 hrs							23.28 – 00.11 hrs							20.33 – 21.04 hrs							05.00 – 05.40 hrs						
	0.2	2	5	10	20	30	50 m	0.2	2	5	10	20	30	50 m	0.2	2	5	10	20	30	50 m	0.2	2	5	10	20	30	50 m	0.2	2	5	10	20	30	50 m
Sardine egg	7	–	2	–	0	0	0	6	7	4	4	3	0	0	4	11	3	2	1	0	0	–	2	1	2	13	6	2	46	22	7	4	3	4	0
Sardine prolarva	0	–	0	–	0	0	0	0	0	0	0	1	3	0	0	0	1	0	1	1	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Etrumeus micropus egg	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	0	1	2	1	3	0	0	1	0	3	3	0
Metridia lucens (copepodid larva)	0	–	0	–	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calanus plumchrus (copepodid larva)	0	–	0	–	0	2	0	0	0	0	0	0	4	1	0	0	0	0	0	3	1	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parathemisto oblivia	0	–	0	–	0	1	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Limacina helicina	0	–	2	–	23	14	14	1	2	3	4	19	27	21	2	0	1	7	12	15	10	–	1	1	5	1	15	96	5	1	1	1	22	22	16
Aglantha digitale	0	–	0	–	3	6	2	0	0	2	7	14	45	63	5	2	7	6	15	56	49	–	3	0	0	1	37	23	7	3	3	4	4	4	0
Euphausia pacifica larva	0	–	0	–	5	0	0	0	0	0	0	3	0	0	1	0	1	0	3	0	1	–	0	0	0	0	0	0	0	0	0	0	0	1	0
young	0	–	0	–	2	2	0	1	0	1	19	4	17	5	21	8	11	4	3	9	1	–	0	0	0	2	0	10	0	0	0	0	0	1	0
Calanus helgolandicus ♀	0	–	0	–	0	1	1	1	2	0	0	1	0	0	0	0	0	0	0	0	0	–	4	4	0	0	0	0	0	1	1	1	1	0	0
♂	0	–	0	–	1	0	0	0	0	1	4	1	1	2	0	0	2	0	1	1	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
stage V	0	–	2	–	2	2	0	2	3	5	17	3	5	2	4	2	3	2	0	4	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0
stage IV	0	–	0	–	2	0	0	1	0	1	8	2	11	0	1	0	1	0	0	4	0	–	0	0	0	0	0	1	0	0	1	0	0	1	0
stage III	0	–	0	–	5	6	0	0	0	1	0	3	26	3	0	0	0	0	2	9	0	–	0	0	1	0	2	0	0	0	0	0	0	0	0
stage II	0	–	0	–	0	0	0	0	0	0	0	1	7	2	0	0	0	0	0	3	0	–	0	0	0	0	2	1	0	0	0	0	0	3	0
stage I	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	0	1	0	1	1	1	0	0	0	0	2	0	1
Calanus tenuicornis (copepodid larva)	0	–	0	–	6	0	1	0	0	1	0	2	4	3	0	0	1	1	4	2	3	–	0	0	0	0	1	1	0	0	0	0	1	0	0
Muggiaea atlantica	1	–	0	–	6	2	0	0	1	0	0	3	0	0	0	1	4	2	2	2	2	–	7	5	7	6	7	6	3	4	6	2	3	6	0

Appended table (continued)

Plankton organisms	May 15														May 21						
	12.30 – 13.08 hrs							16.29 – 16.53 hrs							20.33 – 21.05 hrs						
	0.2	2	5	10	20	30	50 m	0.2	2	5	10	20	30	50 m	0.2	2	5	10	20	30	50 m
Sardine egg	19	12	12	3	4	2	0	32	18	16	2	4	8	0	20	15	17	14	2	10	0
Sardine prolarva	0	0	0	0	3	5	0	0	0	0	1	1	1	0	0	1	0	1	1	2	0
Etrumeus micropus egg	0	1	0	0	1	1	3	2	1	0	2	0	1	1	1	1	0	2	0	3	0
Metridia lucens (copepodid larva)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calanus plumchrus (copepodid larva)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parathemisto oblivia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Limacina helicina	2	1	1	3	1	2	59	20	7	5	2	0	3	42	1	2	0	3	4	67	114
Aglantha digitale	0	0	1	4	4	10	49	1	0	0	0	3	3	18	0	1	0	0	1	3	40
Euphausia pacifica larva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
young	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Calanus helgolandicus ♀	0	0	0	1	0	0	2	0	0	0	1	0	0	1	0	0	0	0	1	0	2
♂	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
stage V	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
stage IV	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	1	3	1
stage III	0	0	0	0	1	2	1	0	0	0	0	1	1	2	1	0	0	0	2	1	0
stage II	0	0	0	0	0	1	0	0	0	0	0	0	2	3	0	0	0	0	0	5	2
stage I	0	0	0	1	0	4	1	0	0	1	1	1	4	0	0	0	0	0	1	13	2
Calanus tenuicornis (copepodid larva)	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	3	1
Muggiaea atlantica	5	3	6	20	19	25	4	4	4	6	16	13	4	3	6	7	7	3	14	5	4

Plankton organisms	May 21							
	16.20 – 16.48 hrs							
	0.2	2	5	10	20	30	50 m	
Sardine egg	2	1	0	2	2	0	2	
Sardine prolarva	0	0	0	0	0	0	0	
Etrumeus micropus egg	0	1	1	0	3	0	2	
Metridia lucens (copepodid larva)	0	0	0	0	0	0	0	
Calanus plumchrus (copepodid larva)	0	0	0	0	0	0	0	
Parathemisto oblivia	0	0	0	0	0	0	0	
Limacina helicina	1	2	2	5	6	13	53	
Aglantha digitale	0	0	0	0	0	2	3	
Euphausia pacifica larva	0	0	0	0	0	0	0	
young	0	0	0	0	0	0	0	
Calanus helgolandicus ♀	0	0	0	0	0	0	0	
♂	0	0	0	0	0	0	0	
stage V	0	0	0	0	1	2	0	
stage IV	0	0	0	1	1	2	1	
stage III	0	1	0	0	2	6	2	
stage II	0	0	0	1	0	17	3	
stage I	0	0	1	2	2	7	0	
Calanus tenuicornis (copepodid larva)	0	0	0	0	0	0	0	
Muggiaea atlantica	6	0	1	5	11	5	4	

卵黄吸収完了時におけるマイワシ稚魚の体重の推定

西　村　三　郎

A Trial to Estimate the Body Weight of a Sardine Larva

By

Saburo NISHIMURA

Abstract

It is difficult to measure the body weight of a sardine larva at the end of prolarval stage separately by direct balancing because of so minute value. Further it is not always easy to obtain specimens of the same size in numbers large enough for balancing in a bunch. Desiccation is also one of the technically difficult problems. Therefore the writer tried to estimate it by indirect ways. The upper limit of estimation was obtained by computing the weight of an ovum in the egg-shell, which was considered to be slightly larger than that of a prolarva. This computation was easily made by solving an equation of neutral buoyancy in a floating egg. The lower limit was obtained by calculating the volume of a larval body multiplied by its under-estimated density. Thus the range of larval wet weight was inferred 0.27 – 0.21 mgr. The writer tentatively abopted 0.23 mgr. or thereabout as the most probable weight of a sardine larva at the end of yolk absorption phase (about 5.0 mm. in total length). Supplementarily conducted experiments using a chemical balance gave measurements of 2.2 mgr. (when moderately desiccated) and 1.7 mgr. (when strongly desiccated) for 10 larvae ranging 4.2 to 6.1 mm. in total length.

よく知られているように，回游性の海産魚類では，1尾の雌魚の放出する卵数はきわめて大きい．一般に万あるいは10万のオーダーである．それにもかかわらず，これらの魚がいちじるしくふえることがないのは卵・稚魚期の自然死亡率が非常に高く，成熟に達する前に大部分が死んでしまうからである．わが国において，数年来，積極的に進められてきた魚類資源の研究は，この発生初期における自然死亡の機構の解析およびその量的はあくがきわめて重要な課題であることを明らかにした。(1),(2)

筆者は，マイワシについて，この初期自然死亡の機構を研究中であるが，とくに卵黄吸収以後における稚魚の飢餓の問題と関連して，この時期の稚魚の体重（湿重量）を知る必要にせまられた．それで，種々文献をあさつてみたが，まつたくその記載がないことを知つた。

通常，マイワシ稚魚は海で採集されるとただちにフオルマリンで固定され，われわれの調べうるのはこの種の標本である。このものについての秤量には，固定による重量変化という根本的な問題を別としても，大

きさの同じ稚魚の標本を数多く揃えにくいこと（稚魚1尾の重量はきわめて小さいので，個々の稚魚についての測定は，化学天秤をもつてしても不可能である）および，脱水の程度を統一することの技術的な困難さがあり，得られる測定値の信頼性は低い。また，海上において，新鮮な標本について秤量をおこなう場合には，それ以上の困難がつきまとう。したがつて，筆者は，次のような間接的な方法で推定を試みた。

Ⅰ．孵化前の胚の重量は簡単に知ることができ，そして，この値は，次にのべる理由から，稚魚の体重の上限を与えるものとみることができる：胚の内部では，低位におさえられた形においてではあるが，たえず代謝がおこなわれて栄養物質を燃焼し，end products を放出している。また，胚の表層原形質膜は，塩類に対しては不透過であり，水に対してもほとんど不透過であるが，微弱な程度において脱水がおこなわれていると考えられる。孵化後も，卵黄吸収完了までは，一般に稚魚は外界から物質をとり入れることをしない。したがつて，表層原形質膜が negative osmosis をおこなわなければ，あるいは，おこなつても無視しうる程度であれば，胚の重量は卵黄吸収完了までは常に減少の過程にあるといえる。

いま，マイワシ卵の容積をV，その平均密度をσ，卵黄＋胚の重量をY，その容積をv，囲卵腔液の密度をρ_i，卵膜の重量をmとすれば，次式が導かれる：

$$(1)\quad \sigma V = Y + (V - v)\rho_i + m$$

ただし，卵膜はきわめて薄いものであるから，その容積は上式では省略してある。

卵が海水中で浮上も沈降もしない場合には，σは周囲の海水の密度ρ_eと等しいから，(1)式は変形されて：

$$(1')\quad Y = v\rho_e - (V - v)(\rho_i - \rho_e) - m$$

発育段階がCa期（胚体がなかば形成されて，その尾芽が卵黄を離れはじめた直後の段階）にあるマイワシ卵についての実験の結果では，これは，温度21～22°C，塩素量18.76‰の海水と比重的に釣り合う。すなわち：

$$\sigma = \rho_e = 1.0235$$

vについては，これは，球形の卵黄とそれをとりかこむ微小な円柱形の胚体とからなるとみることができる。フオルマリン固定標本についての測定によれば，この発育段階の卵黄の半径は平均0.38mmである。固定に際しての収縮の度合については不明であるが，スケトウタラ卵巣卵については約7％という値が得られている。[3] この値がマイワシ卵にもあてはまると仮定すれば，生時の卵黄の半径は0.40mmとなる。したがつて，その容積は：

$$4/3\pi\,(0.040)^3 = 0.27 \times 10^{-3}\ (\mathrm{ml})$$

また，胚体の容積は：

$$\pi\,(0.005)^2 \cdot (0.15) = 0.01 \times 10^{-3}\ (\mathrm{ml})$$

したがつて：

$$v = 0.28 \times 10^{-3}\ (\mathrm{ml})$$

(1')式の右辺の第2項は，第1項と比較して省略してさしつかえないであろうと考えられるが，

$V - v = 0.002$，$\rho_i - \rho_e = 0.01$ とおけば*，0.02×10^{-3} となる。

mについてはまつたく不明であるが，おそらく非常に小さいものであろう。ここでは省略することにする。

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* 卵黄径は卵径のほぼ½であるから：
$V - v = 4/3\pi\,(0.08^3 - 0.04^3) = 0.002$
囲卵腔液は海水にごく微量のコロイド物質（おそらく多糖類あるいは糖タンパク）の添加したものであると考えられる。コロイド物質の密度を1.4，その重量含有率を3％とすれば：
$\rho_i = 1.4 \times 0.03 + 1.0235 \times 0.97 = 1.0348$
したがつて：
$\rho_i - \rho_e = 0.01$

したがつて：

$$Y \lesssim (0.28 \times 1.0235 - 0.02) \times 10^{-3} = 0.27 \times 10^{-3}\ (\mathrm{gr})$$

すなわち，卵黄吸収時における稚魚の体重（湿重量）は 0.27 mgr 以下と推定される。

Ⅱ．卵黄吸収完了直前の稚魚の容積は比較的容易に求めることができるので，これと，最も確からしい稚魚の密度とを用いて，その体重を推定することができる．

この時期の稚魚の基本的形態はきわめて細長い円柱とみることができる。頭部はやや膨大しており，これは楕円体をなしている．尾部は次第に細まつているが，胴部下面に沿つて走つている腸管の容積をもつて補充すると，体幹部は一様な太さの円柱とみることができる。したがつて，稚魚を上述のような楕円体と円柱との組合わせとみなしてその容積を計算した。その結果，全長4.8mmのものについては 0.19×10^{-3} ml，同じく 5.1mm のものについては 0.21×10^{-3} ml という値を得た。ただし，固定による収縮は考慮に入れていない。したがつて，やや過小に偏つているであろう。これらはいずれも卵黄吸収完了直前の発育段階のものであつて，おそらく，まだ摂餌はしていないと思われる。ここでは平均容積として 0.20×10^{-3} ml をとることにする。これらの稚魚の体幹部の背側および腹側は，その正中線に沿つて連続して走るかなり巾広い膜鰭によつて縁どられているが，計算に際してはこれの容積を省略した。したがつて，この意味においても，上の値は過小に傾いている。

次に，稚魚の平均密度についてであるが，死亡直後の新鮮な標本は通常の海水中ではかなり急速に沈降する。稚魚の形態が極端に細長く，かつ，巾広い膜鰭を有していて，沈降に際しては水の粘性抵抗を強く受けるように浮游生活に適応しているのにもかかわらず，急速に沈降することは，稚魚の密度は海水のそれよりもかなり大きいことを物語る。すなわち，1.024 よりもかなり大きい。しかし，1.2 より大きくなることはないであろう。ここでは，結果を過小に偏らせるために，すこし小さめに，1.05 という値をとることにする。その結果，稚魚の体重は 0.21 mgr 以上ということになる。

以上から，卵黄吸収完了直前におけるマイワシ稚魚の体重（湿重量）は 0.21～0.27 mgr の範囲内にあることが推定された。この範囲内のどの辺に落ちるものであるかはわからない。卵黄吸収完了時における稚魚の大きさ自体にかなりの個体変異があるので，一概に，ある 1 点の値を挙げて示すことはできないだろう。しかし，その平均的な値としては，0.23 mgr の程度をとるのが妥当ではないかと思われる。

最後に，実際に化学天秤を用いて秤量をおこなつた結果について記す．しかし，前述したように，この方法ではきわめて rough な値しか求められないのであつて，ここでは，単に上の推定値を check するという意味でおこなつたのである。

全長 4.2～6.1mm（前期稚魚期の中頃から後期稚魚期のはじめまで）の稚魚10尾について，水洗してフォルマリンをぬき去つた後，濾紙上で付着水をほぼ完全にとりのぞいた場合，および，単に drip だけをのぞいた場合についてそれぞれ測定したところ，1.7 mgr および 2.2 mgr という値を得た。測定直後稚魚を検鏡して，前の場合にはかなりの程度に，また後の場合にはやや乾燥していることを認めた．いずれも自然状態における形態からいちじるしく shrink していた．したがつて，上の測定値は幾分過小に傾いているであろう。この点を考慮すると，さきに求めた推定値の妥当性に関してなんらかの示唆が得られると思う。

おわりに，稿電にあたられた日本海区水産研究所の安尾惠子嬢に感謝の意を表する

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Some Considerations Regarding the Amount of Foods Daily Taken by an Early Postlarva of Sardine

By

Saburo NISHIMURA

Abstract

Using the most probable value for the first coefficient of growth energy in a sardine postlarva which is assumed to feed principally upon tiny larval forms of copepods and other zooplankters, the amount of its daily ration in the natural environment has been estimated. The critical density in food animal distribution fulfilling the requirement by the postlarva has also been discussed.

Introduction

Much discussion has been made concerning the food problem of marine fish larvae since HJORT (1914, 1926) suggested hunger as one of the most critical causes for the tremendous reduction in number in the early life history of those marine teleosts which are very fecund. Some authors obtained results favorable to HJORT's opinion, whilst others gave different conclusions and showed scepticism.

Through the intensive cooperative sardine resources investigation in Japan carried out since 1949, it has been cleared up that the Japanese sardine (*Sardinops melanosticta*) also undergoes a marked reduction in number during the rather short period of early life history. According to NAKAI *et al.* (1955), no less than 99.9 % of the amount of spawn is lost during the period (about 60 days) up to the time when the larva reaches 20 mm. in total length. As to the possible cause for this high mortality rate, there have been presented by researchers many factors to be responsible, among which starvation by lack or deficiency of propor foods for early postlarva is also included.

It is a distinguished fact that, while engaged in the gut content observation of sardine postlarva, one is frequently confronted with a vast proportion of specimens with empty gut. The younger the larva, the larger the fraction of empty gut specimens to the total examined. YAMASHITA (1955) observed that only in eight individuals out of 100 sardine postlarvae examined which were less than 14 mm. in length traces of foods were hardly recognized, while 117 contained foods out of 180 larvae ranging 21 - 40 mm. in length and almost all individuals were fed in specimens with the size larger than 41 mm. inclusive.

The chances that the observer recognizes foods in the larval gut are determined by the magnitude and time distribution of incidence of feeding, the amount

of foods taken and the speed and the rate of digestion in the larva. The low and timely restricted incidence of feeding accompanied with the small amount of ration as well as the rapid and complete digestion will give rise to an empty gut most of the time. MORRIS (1955) has recognized through laboratory observation that digestion proceeds by no means at a very rapid rate nor appears it to be very complete for such diets as nauplii and veligers. This and other similar observations may eliminate the high digestion speed and rate as the cause for so often encountered empty guts. There comes next the question how large is the amount of foods a sardine postlarva must take per unit time in order to carry out the maintenance as well as the growth metabolism sufficiently, or at the minimum level at least.

The present paper concerns this problem. Another problem regarding the incidence of feeding will be discussed in a different paper.

Estimating Formula

Suppose that, by taking foods amounting to $r=Rdt$ during the time span dt, a sardine postlarva has increased its body weight by dw in the same period, then

$$K_1 = \frac{dw}{r} = \frac{dw}{dt} \Big/ \frac{r}{dt} = \frac{dw}{dt} \Big/ R,$$

where K_1 is the first coefficient of growth energy (RICKER, 1946) or the efficiency of conversion and R is the daily ration when the day is taken as unity of time. The above equation is transformed into

$$R = \frac{1}{K_1} \cdot \frac{dw}{dt} .$$

Let L be the total length and W the body weight of the larva. During the early postlarval phase when L lies between 0.45 and about 1.0 cm, W can be expressed as equal to aL^3, where a is a constant. Thus we have

$$R = \frac{3aL^2}{K_1} \cdot \frac{dL}{dt} .$$

According to NISHIMURA (1957), $W = 0.23 \times 10^{-3}$ (gr.), when $L = 0.50$ (cm.). Hence $a = 1.84 \times 10^{-3}$.

Discussion on K_1

When a larva is taking foods of high nutritive value, K_1 may no doubt be high. Contrarily when it is taking foods of low nutritive value, K_1 may be low. A few laboratory experiments have hitherto been made in order to estimate the magnitude of K_1 in young fishes of several kinds, among which a sardine larva

is regretfully not included. SCHOLZ (1932) showed that K_1 for a one-year-old pike which had been reared with fish meat as foods under the optimum condition was 29–36 % and that some large individuals of 0-age also had given similar value for K_1. According to KARZINKIN (1939), the yearling pike which had been fed with various items of natural diets showed K_1 to be 24–27 % under the optimum experimental condition. Whenever food particles too small in size for the fish were given, however, the value of K_1 dropped rapidly. He conducted this rearing experiment on the larval and young pikes of 9 to 80 days old and found that K_1 was lower during the first 10 to 20 days than during the following days. PENTELOW (1939) obtained the value up to 29 % as K_1 in the young brown trout which had been fed with Gammarus. HATANAKA & TAKAHASHI (1956) observed that K_1 for the young mackerel (4–9 gr. in initial body weight) was 27–39 % when reared with anchovy under the water temperature 22.0–24.5°C.

There are considerably many observations regarding the natural diets of sardine larvae and it is generally believed that the principal foods are nauplii and eggs of copepods, and at times Lamellibranchia and gastropod larvae. Considering the fairly large proportion of water and indigestible integuments in copepod larvae, and further taking into account the supposed differences in amino and fatty acid compositions of proteins and fats of copepods from those of fish larvae, K_1 may not perhaps reach so high a value as cited above. But it is yet undetermined how high the value for K_1 is to be taken in a postlarval sardine. Therefore, with foregoing lines in mind, we must be contented with tentatively assuming that 0.2 or thereabout may be most valid, when the larva is feeding in the main upon the nauplii and eggs of copepods.*

Discussion on dL/dt

As for the larval growth rate of the sardine, we have only a few estimations. According to NAKAI *et al.* (1955), nearly 20 days appear to be needed for the sardine larva to grow from 5.3 to 8.3 mm. in length. Assuming a constant growth during this interval, $dL/dt = 0.015$ (cm. per day). But, as these authors have indicated, the growth rate may be somewhat smaller than this value in the early half period and larger than that later, because the early development is considered to be exponential as regards time. AHLSTROM (1954) has estimated on the larva of California sardine (*Sardinops caerulea*) that it may need 3.9, 3.3 and 2.9 days respectively for growing successive 1 mm. from the initial length of 5.26 mm. Hence, dL/dt will be in the average 0.026, 0.030 and 0.034 (cm. per day)

* When, however, the larva is feeding mostly upon such diets of low nutritive value as decaying remains of phytoplankton and humic substances suspended or dissolved in sea water, the value of K_1 may be doubtlessly very low. In this situation, the larva may have to take in a vast amount of such matter in order to maintain itself and to grow.

respectively for the larval size ranges 5.26 - 6.25, 6.26 - 7.25 and 7.26 - 8.25 mm. Thus the value of growth rate in this case is about twice as large as that by NAKAI *et al.* (*op. cit.*).

We shall make computation of the amount of daily ration R using AHLSTROM's estimate.

Computaion of Daily Ration

Under are given the results of computation in the amount of daily ration in mgr. taken by a sardine postlarva belonging to different size ranges in respective cases $K_1 = 0.25$, 0.20 and 0.15. The midvalue of each size range was taken as L.

Size range in mm.	5.26 - 6.25	6.26 - 7.25	7.26 - 8.25
Duratron in days	3.9	3.3	2.9
Mean body weight in mgr.+	0.35	0.57	0.86
$K_1 = 0.25$	0.19	0.30	0.45
0.20	0.24	0.38	0.56
0.15	0.32	0.50	0.75

+ Mean body weight was calculated from the equation: $W = 1.84L^3$

From the table, we see that when $K_1 = 0.20$, for example, a sardine postlarva is daily taking foods 0.70 - 0.65 time as much as the body weight (if computed using the estimate of growth rate by NAKAI *et al.*, however, the value is reduced to about half), and that the amount of food animals consumed during the period when the larva grows from 5.26 to 8.25 mm. in length (10 days, according to AHLSTROM; and nealy 20 days, according to NAKAI *et al.*) comes up to about 3.8 mgr.

Consideration

As mentioned in the preceding section, a sardine postlarva of 5.75 mm. in length takes daily foods amounting to some 0.24 mgr. in the natural environment. Assume that the foods be composed exclusively of larval forms of copepods and other planktonic crustaceans. According to my measurement, the widest mouth aperture in a postlarva of this size is about 0.60 mm. × 0.38 mm. And doubtless the diameter of the pharyngeal pass is considerably smaller than 0.38 mm., although it may be expansible to some extent. Regarding fhe larval crustacean as a sphere or an ellipsoid in shape, it can be stated that those forms which are smaller than 0.35 mm. and its neighbourhood in diameter or in length of the longer axis will be more frequently taken by the fish larva than larger food

animals, because of the distinguished predominancy in number and the greater feasibility to be ingested of the former over the latter.*

Among the crustacean animals occurring in great quantities in the nursery grounds of sardines along the Japan Sea coasts, copepod species such as *Calanus finmarchicus* (*helgolandicus* type), *C. tenuicornis, Paracalanus parvus, Corycaeus anglicus, Oncaea venusta* and *Oithona spp.* are most important. We now take *Calanus finmarchicus*, the most large-sized of those plankton copepods commonly occurring on the nursery grounds, for particular consideration. GIBBONS (1933) observed the nauplial growth in this copepod and described the body length at respective stages as follows:

Stage I	240 μ
Stage II	270 μ
Stage III	320 μ
Stage IV	360 μ
Stage V	480 μ
Stage VI	810 μ

We can now imagine nauplius stages I and II to constitute by far the greater proportion of this copepod speies taken by the postlarvae. Stage III may be also taken, but in smaller proportion; because the strongly setose and well developed appendages may be obstacle to ingestion. According to LEBOUR (1916), on the other hand, the body length of nauplii of the same species is:-

Stage I	210 μ
Stage II	270 μ
Stage III	420 μ

It is thus considered that a sardine postlarva 5.75 mm. in length may take in mostly nauplius larvae younger than stage III and of course copepod eggs as well.

Based on the data afforded by GIBBONS (*op. cit.*) and by MARSHALL & ORR (1955), the wet weights of these nauplii are roughly estimated as follows: 0.004 mgr. at stage II and 0.003 mgr. at stage I. In this connection, it may be added that an ovum of this copepod weighs about 0.002 mgr.

We can now mention with some generality that the sardine postlarva of the considered size takes principally food animals the individual weight of which is 0.004 mgr. and less, if assumed nearly equal body density in various living food animals including other copepod species and molluscan larvae. This leads us to the following conclusion: the sardine larva has to take daily 60 individuals and more of such food animals as available to it. How high density of distribution of food animals is then sufficient to meet this requirement?

* Food organisms actually found in the postlarval gut are usually smaller and in many cases by far smaller than this size.

Consider the probability of encountering of a sardine postlarva with its food animals. Let V be the water mass in which one postlarva is contained in the average, n the number of available food animals in the same water mass, v the relative speed of the postlarval movement to any food animal and r the range of perception of the postlarva. Then encountering frequency per unit time f is approximately given by the following equation:

$$f = \pi r^2 v \frac{n}{V}$$

According to my own estimation (NISHIMURA, MS), $V \fallingdotseq 1 \sim 2$ m^3 in the intermediate layers where sardine early-stage larvae are abundant in the nursery ground off Noto Peninsula, Japan Sea. Uniform distribution of food animals may be assumed in the water volume of this degree of dimensions. Put $n/V = N$, where N is the density in food animal distribution in this water volume. Further put $f \geq 60/(24 \times 3600)$ sec^{-1} and $v \fallingdotseq 1.0$ cm. per sec. As to the value for r, 0.1 cm. and its neighbourhood will be appropriate when the postlarva is to scout foods by smell, and 0.5 cm. will be tentatively assumed when it is to find foods by sound or vibration of medium given rise to by movements of any food animal. In this connection, it may well be mentioned that by this developmental stage the sardine postlarva is not yet equipped with effective visual function. Thus we have

$N \geq 0.022$ per ml. or 2.2×10^4 per m^3. ($r = 0.1$ cm.) or
0.00088 per ml. or 8.8×10^2 per m^3. ($r = 0.5$ cm.).

That is to say, the postlarva can maintain itself and grow in the water mass in which the density in distribution of its food animals is higher than 2.2×10^4 per m.^{3} or 8.8×10^2 per m.^{3}, respectively, according to the type of feeding, *i.e.*, "olfactory" or "auditory".

It should be, however, remembered that the sardine postlarva by no means continues to swim at the constant speed above given throughout the time, and moreover that it does not always succeed in capturing the food animal when the latter enters the range of perception of the former, as SOLEIM (1942) depicted regarding herring larvae. So the above-given value for N may perhaps be much under-estimated.

Further we see, from the foregoing equation, that, as the postlarva grows on, its encountering frequency with food animals will be rapidly increased through the distinguished expansion in the range of perception after the establishment of visual function, the greater speed in movement and the accomplished skill in capturing on one hand, and through the reduction in size limitation upon food animals resulting from the enlargement in mouth aperture on the other. Thus we may safely mention that there may be or may not be for the sardine postlarva the possibility to starve to death, and that if there actually be, the rather short

period just after the exhaustion of yolk reserves may be most critical.

Future Lines of Research

In the present paper, the first coefficient of growth energy K_1 has been rather arbitrarily assumed, because we have no data proper concerning the study on this coefficient in very early larvae. So the determination of this right value is much desired. The same can be said with much more accentuation on the critical density in food animal distribution. It may be very important to clearify whether the early postlarvae are olfactory or auditory scouters and by which time they become equipped with effective visual function and begin to search foods optically. The speed and the duration in larval movements are also desired to determine.

When all these items have been cleared up, we can obtain the more precise figure of the daily ration in a sardine postlarva and criticize finally the validity of the opinion emphasizing starvation as the main cause for the tremendously high mortality rate in the early life history.

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A Transformation of Brain Form Following the Growth of *Chasmichthys gulosus* (GUICHFNOT)

Kiyoshi UCHIHASHI and Yoshinori OGAWA

It is admitted by the general phenomenon of animate creation that a behaviour and a form would be transformed in keeping with the growth of *Chasmichthys gulosus*. Up to the present, many of research workers have made a specia' study of transformation of outside form and digestive structure accompanying ecological adaptation. However, with the growth of transformation of brain form, the sense-centre, a question concerning ecological adaptation remains untouched, but as to the said question nobody but a writer UCHIHASHI ('53, '55) is to the point.

Upon this, we turned our attention to a fact that in the early days of *Chasmichthys gulosus* they live a swimming life and then turn to living in the bed as they grow older. From this point of view, we made a special study of transformation on the connection between brain form and behaviour respectively in their growth phase.

The growth of *Chasmichthys gulosus* and its behaviour

Chasmichthy gulosus, as a rule, swims among the reef in the shore and belongs to a goby family of fishes. Ecological adaptation, from hatching to their growth, explains as follows:

(a) A young fish after hatching, in general, live a swimming life until side of 25 millimeters in the total length, (b) from the total length of 20 millimeters or thereabout, it takes an action after the fashion of creep once in a while, (c) from the total length of 30 millimeters or so it turns to living in the bed of water, (d) as regards a food fad, preys upon Copepoda while leading a swimming life and when turned to a bed living it will be turned into omnivora, (e) up to the total length of 20 millimeters or so it lives gregariously but when grown up over 20 millimeters, gregarious living will go down, by degrees, and it will perfectly be vanished in the phase of bed living and (f) on the other hand, there are positive phototaxis as far as about 15 millimeters in the total length, grows weak with the growth and will completely be vanished over 35 millimeters.

Brain from of adult *Chasmichthys gulosus*

With respect to an external brain form of adult fish, a goby family of fishes has a distinctive form of optic lobes. As writer UCHIHASHI explained on that point of *Chaeturichthys hexanema* BLEEKER and *Boleophthalmas pectnirosis* (GMELIN),

fatty matter to cover the brain of *Chasmichthys gulosus* is comparatively abundant, whole brain will more or less be depressed lengthways, a straight line which to knot the apex of olfactory lobes and corpus cerebelli will be inclined forward in some degree, and the apex of optic lobes is a little shorter than this straight line.

All conspicuously big olfactory lobes, with the exception of olfactory bulbs resemble a bottle in shape and are small, and stick to olfactory lobes. Respective hemisphere of olfactory lobes are remarkably jut out to the outer side, the dorsal view of respective hemisphere is analogous to triangularity without corner and has three projecting points at the rear of the back. Olfactory lobes are larger than optic lobes. Epiphysis is short as well as small.

Just in front of thalamus, a right side nerve of chiasma opticum places upwards in decussate nerve, optic nerves are comparatively thick, section is almost ellipse, additionally thick.

In the respect of thickness, this cannot stand comparison with that of olfactory nerves. Infundibulum is large, while inferior lobes are corpulent ones and spread forward especially expaned in the rear. Saccus vasculosus is located along the lower part of median line and well developed in a shape of an obtuse angle and a wedge. Hypophysis is a cone and small.

Optic lobes viewing from the rear presents an oval shape and are small and its two shapes of blades are not perfectly spread in the direction of rear.

Corpus cerebelli is small, its back-viewing is almost similar to a rectangle without corner and nothing but to extent to the rear only.

Eminentia granularis is small, valvula cerebelli is a small projection in shape and is omnipresent in the optic ventricle. Medulla oblongata is long and expanded. Crista cerebelli enlarges like a levee in shape and both leaves come in touch with each other.

Ventriculus quartus is long and slender unfolding at the mouth just a bit, both sections in which facial lobes and vagal lobes located are incorporate, the two in one and enlarges a little on both sides of ventriculus quartus. Viewing the brain from its all aspect, telencephalon is the largest and comes next in order of optic lobes, infundibulum + inferior lobes, medulla oblongata and corpus cerebelli.

Transformation of brain form with the growth

An early stage of swimming (total length 5～10 millimetres)

Optic lobes are large in particular as compared with the respective parts of brain. Telencephalon comes next in this point, however, olfactory bulbs are extremely small. A back-viewing of olfactory lobes presents a long ellipse,

optic lobes and olfactory lobes are not conjoin with each other, front part of diencephalon would be seen from the rear, moreover, ganglion habenulare would also be seen.

Optic nerves are extremely large, a right-side nerve is placed on the top and crosses in front of infundibulum. A small one in comparison is infundibulum and interior lobes are at once small and long ellipse. As for saccus vasculosus, its fixed location is only enlarged, but its outline is not ascertained yet. To see from back, corpus cerebelli is nearly round shape and small and project only in the upward direction.

Valvula cerebelli, of optic ventricle, is a three-cornered projection in small shape and is omnipresented in the rear part of optic ventricle. Eminentia granularis is rarge and long ellipse: in addition, an expansible one. Medulla oblongata, from the back-view, is thickly protruded and almost elliptical.

As stated above, it would be recognized that among the brains, the largest one is optic lobes and come next in order to telencephalon, infundibulum + inferior lobes, medulla oblongata and corpus cerebelli respectively in respect of dimensions.

A middle stage of swimming (total length 11~15 millimeteres)

As well as in an early stage of swimming, optic lobes are of the largest among respective parts of brain. The largest one, second only to optic lobes, is telencephalon but dimentions of olfactory bulbs against olfactory lobes is extremely increased.

On the other hand, the back-view of olfactory lobes is six to eighteen in contrast to the previous stage of swimming, but it has a slight fissure extending from 2 to 3 in the rear of the back. In the previous stage of swimming, there are substantial aperture between rear end of olfactory lobes and front end of optic lobes, where we can see ganglion habenalare, but an excessive change in this stage of swimming is that a rear end of olfactory lobes and a front part of optic lobes are associated with each other.

Though, optic nerves, infundibulum and inferior lobes have no remarkable transformation, especially inferior lobes are beginning to expand as well as enlarge. An outline of triangular saccus vasculosus would be able to recognize clearly.

Optic lobes are enlarged to some extent from the previous stage and have projected in the direction of the rear.

The back-viewing of corpus cerebelli, in the previous stage, was round shape, but in the middle stage it is extended a little to the rear. Also in this stage, as for valvula cerebelli, a hollow would be formed on the end of its rear, and eminentia granularis would only be an oval shape without any growth, however,

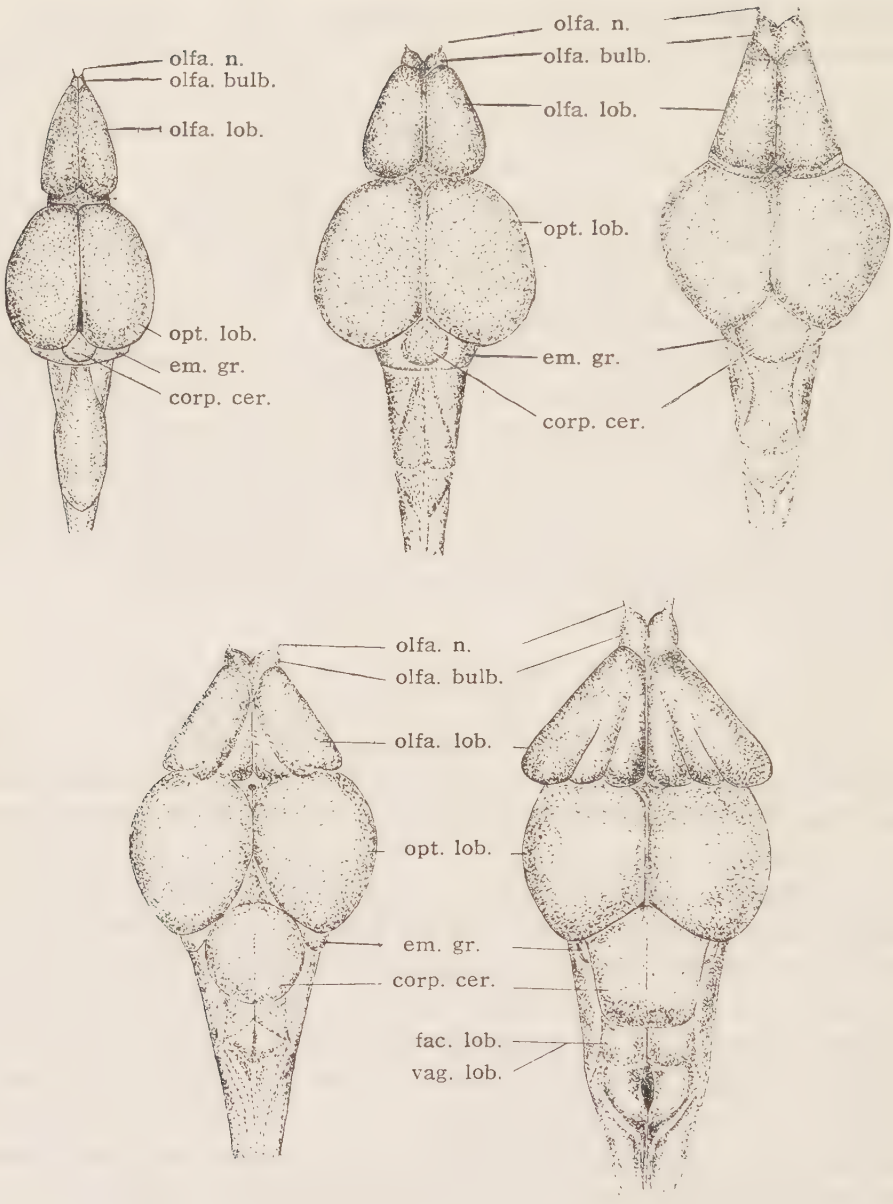

Fig. 1. Development of brain of C. gulosus (dorsal view)

(1) Total length 7mm × 40
(2) Total length 10mm × 40
(3) Total length 15mm × 20
(4) Total length 30mm × 20
(5) Total length 100mm × 20 (adult)

olfa. n., olfactory nerve, olfa. bulb., olfactory bulb; olfa. lob., olfactory lobe; opt. lob., optic lobe; em. gr., eminentia granularis; corp. cer., corpus cerebelli; fac. lob., facial lobe; vag. lob., vagal lobe.

as other parts grows older so eminentia granularis will not be marked little by little in comparison with the grown-up other part.

In contrast to the previous stage, medulla oblongata also differentiate together

with corpulence, but a part to be recognized as crista cerebelli hereafter is enlarged a little only.

When turned to a total length of 15 millimetres a rear side of olfactory lobes enlarges a little. Its back-view nearly assumes a triangular gimlet in shape and optic lobes also make a growth gradually and assumes an ellipse in the back-view. Corpus cerebelli will extend gradually to the rear and forms an appearance to cover the upside of crista cerebelli.

Both infundibulum and inferior lobes will expand gradually. However the rear part of each hemisphere of inferior lobes will not come in contact with, and saccus vasculosus assumes a triangle in shape along the median line between the two leaves.

Out of medulla oblongata, facial lobes, vagal lobes and crista cerebelli, crista cerebelli will narrowly be able to distinguish as a projecting part.

The latter stage of swimming (including creeping period) and the early stage bed living in the water

When turned to a total length of 20 millimetres it is a time that young fishes make a creeping action, but leading characteristic in this phase indicates that olfactory lobes gradually expand adding globular shape as a whole and nearly presents a triangle in the back-viewing. More than half of the rear side of crista cerebelli will be covered by corpus cerebelli in extending backwards gradually.

A distinction between vagal lobes and facial lobes of medulla oblongata is not clear, but a section in which both lobes to be formed is a projection. An opened section of ventriculus quartus is small and to be a diamond shape on the whole. Dimensions of respective brain parts in precedence in this growth phase does not differ from that of previous.

When in excess of an overall length of 30 millimetres, a back-viewing of olfactory lobes presents a triangular form, reveals a streak in its rear and its outside section expands to a high degree. In other words, it has two projecting sections, a streak in the inner part is small and the other one in the outside is large.

Both infundibulum and inferior lobe expand in a marked degree and respective lobe of inferior lobes come in touch with each other at their rear. The extremity of saccus vasculosus extends more than the rear part of inferior lobe and is about the same as the sharp of adult fish, at the same time, corpus cerebelli and valivula cerebelli are also come up to the shape of adult fish. A straight line to tie a top of corpus cerebelli and olfactory lobe inclines forwards a little.

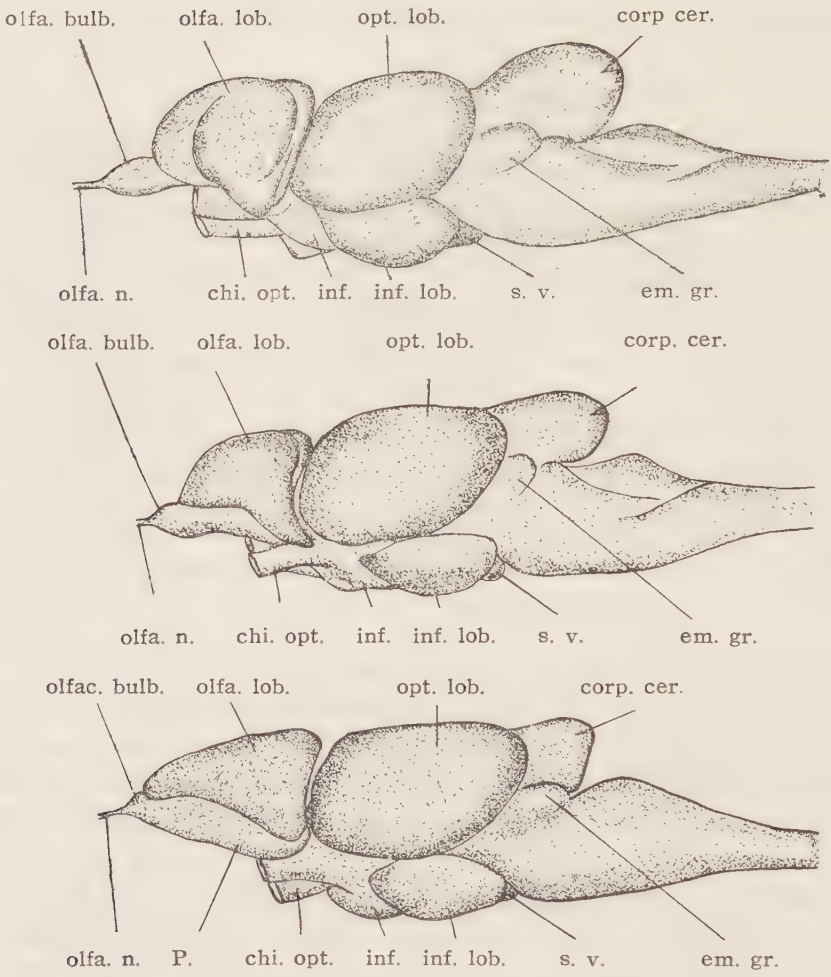

Fig. 2. Development of brain pattern of C. gulosus (Lateral view)

(1) Total length 100 mm × 10 (adult)
(2) Total length 30 mm × 20
(3) Total length 15 mm × 30

olfa. n., olfactory nerve; olfa. bulb., olfactory bulb; olfa. lob., olfactory lobe, p., parethalamus; chi. opt., chiasma opticum; inf., infundibulum; inf. lob., inferior lobe; s. v., saccus vasculosus; opt. lob., optic lobe; em. gr., eminentia granularis; corp. cer., corpus cerebelli

In this phase they move into a swimming life in the depth from that on the surface. Three projecting points would be recognized on the back of olfactory lobes in a gradation of 45 millimetres in the total length. However, while in this phase olfactory lobes are still smaller than optic lobes, but respectively other brain parts would be an adult fish type on the whole.

In the total length of 70 millimetres or so, size ranking of respective brain parts are transformed into an adult fish type.

Explanation mentioned above is a summary concerning transformation of the

brain form attending on growth, but a remarkable section of transformation is olfactory lobes of telencephalon and expand more and more immediately after incubation.

Just as respond to this transformation, medulla oblongata will also make progress. Eminemtia granuraris which had developed in the early stage will be shaken in its development together with the growth and when they enter upon a swimming life in the depth of the water, an eminemtia granuraris will barely be distinguished on the ground of excessive development of the other brain parts. In addition, a transformation of saccus vasculosus, as states below, is conspicuous, too.

Saccus vasculosus, as stated before, is located on the end of median line of inferior lobes. JHONSTON ('06), DAMMERMAN ('10), KAPPERS ('21) and UCHIHASHI ('53) its process.

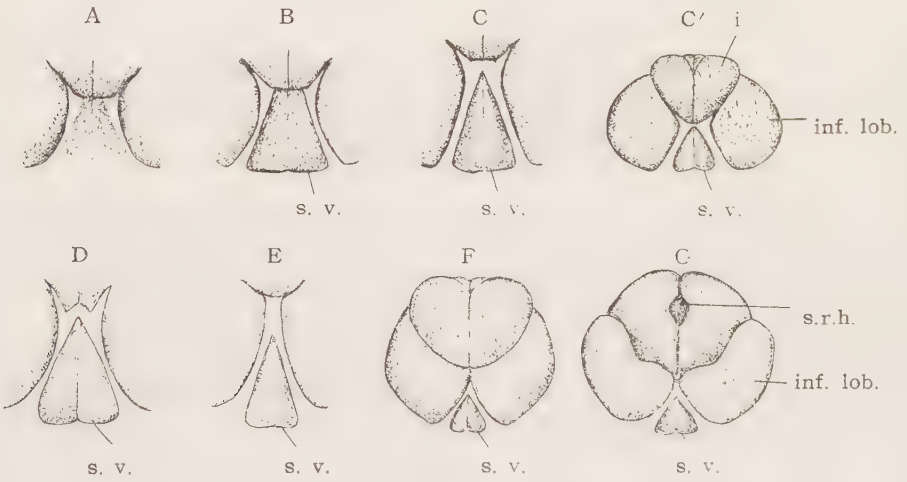

Fig. 3. Ventral view of inferior lobes and succus vasculosus

(A) Total length 9~10 mm
(B) Total length 11~12 mm
(C) Total length 14~15 mm
(C)′ Total length 15 mm
(D) Total length 17~20 mm
(E) Total length 25 mm
(F) Total length 30 mm
(G) Total length 100 mm (adult)

s. v. succus vasculosus; inf. lob., inferior lobe; i., infundibulum; s.r.h., sulcus recessus hypophysis

In an investigation on this organ's form and organism, UCHIHASHI recognized 13 kinds about 72 kinds of adult teleosts which perceive hydraulic water pressure and its form and size indicate a depth living in water, he concluded. With respect to *Chasmichthys gulosus*, we can not recognize externally about 9~10 millimeters, but when it reached total length of 11~13 millimetres, we can recognize its protuberant part only and its outline is not clear. When reached to total length of 14~15 millimetres we can recognize its existence clearly. Form

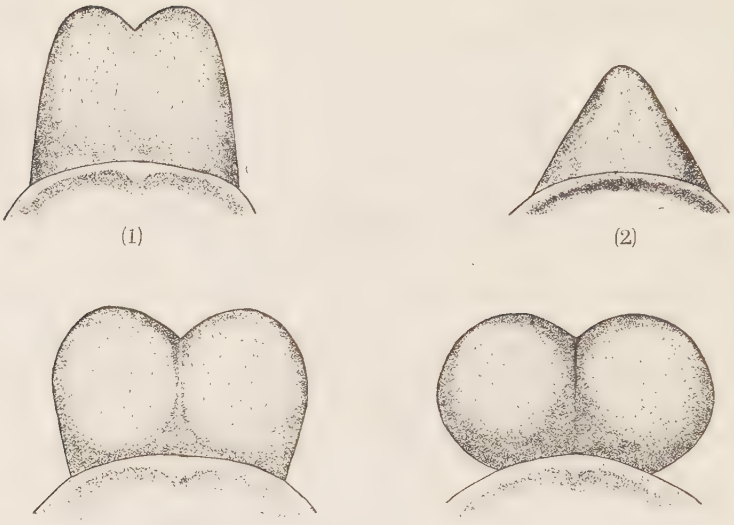

Fig. 4. Dorsal view of "Valvula cerebelli"
(1) Total length 10 mm
(2) Total length 20 mm
(3) Total length 30 mm
(4) Total length 100 mm (adult)

is similar to heart type, its front end comes in touch with infundibulum and back end is placed in front of the back end of inferior lobes.

Meanwhile, with the growth, it extends to the back with the development of inferior lobes. And form of saccus vasculosus is changed into wedge type.

According to UCHIHASHI's classification, ('53) it means an acute-angled wedge type.

Relations with ecological adaptation

With respect to relations between change of external form of brain and ecological adaptation is stated as per enclosure. Until 10 millimetres or so of total length, its swimming power is weak and leads a swimming life in a throng among seaweeds or reef of the nearest shore. Gill raker, in this phase, is a beginning of formation and the digestive organ advances in a bee line. The brain form, in this phase, is especially large at optic lobes as compared with the respective brain parts and considerably large is eminentia granularis. While vagal lobes or facial lobes are not well developed and is entirely brain form of a visual type.

In the next, in the phase of surface swimming in a throng, a sucking-disk of the abdomen is formed, gets a tooth through, extension in the intestines and

Table 1. Relation Between Transformation of Brain Form and Organism By the Growth of *Chasmichthys gulosus* (GUICHENOT)

Full Length	Form of Brain	Swimming Region	Feed	Remarks
7 ~ 10 mm	Optic lobe is considerably large in comparison with respective brain parts. Eminentia granularis is markedly protruded Saccus vasculosus is not clear The vagal lobe and facial lobe of medulla oblongata is not distributed and is a single thick protuberant part. Valvula cerebelli is a triangle small cupola	Among reef or marine plants Intensely positive phototaxis	Unknown	
11 ~ 15 mm	Corpus cerebelli is only expanded to the rear Eminentia granularis is gradually getting unclear Saccus vasculosus is narrowly recognized Valvula cerebelli forms a circular cupola Crista cerebelli is getting clear	Group swimming on the surface region. Intensely poistive phototaxis	Nauplius larva *Setella sp* *Clonene sp*	Forms sucking-disk Early stage of formation of the teeth Things in the stomach are getting clear
16 ~ 20 mm	Side part of the rear of olfactory lobes gradually make their growth. Corpus cerebelli extends toward rear little by little Inferior lobe become fat and large Medulla oblongata finally expand	Group swimming on the surface region. Intensely positive phototaxis	Copepoda Isopoda	Respective fin completed Digestive organ is at most same as that of adult fish
21 ~ 25 mm	Olfactory lobes make growth little by little and lobes posterior cover more than half part of the crista cerebelli Medulla oblongata become fat and large Saccus vasculosus become the same with the grown-up fish as a whole	Sometimes take a creeping action Separate from group swimming by degrees Positive phototaxis is gradually getting unclear	Copepoda *Chasmichthys gulosus* (young stage)	Teeth form as that of adult fish Digestive organ is same as that grown up fish
26 ~ 30 mm	The order of the size of respective brain parts through all stage of not-grown-up fish follows Optic lobes, infundibulum and inferior lobes, olffactory lobes, Medulla oblongata, corpus cerebelli	Removes gradually to the depth of the water	*Chasmichthys gulosus* (young stage) Small shaped shell (top-shell)	Gill rekars are complete shape of adult fish
31 ~ 40 mm	Two projecting parts would be recognized in a grown-up olfactory lobes Infundibulum and inferior lobes are remarkably expanded Corpus cerebelli and valvula cerebelli are become the shape of grown-up fish There are three projecting parts at respective lobes of olfactory lobes. But they are smaller than optic lobes. Others are almost the shape of adult fish	Bottom	Same as above Small shaped shell (top-shell) Green algae *Ligia exotica* Amphipoda	Fin and speckle are complete shape of adult fish
Adult fish	When exceed 70 mm olfactory lobes are become larger than optic lobes, and the order of respective brain parts of adult fish are olfactory lobes, optic lobes, Infundibulum + inferior lobes, Medulla oblongata and corpus cerebelli	Bottom	Same as above	

distinction of the stomach and bowels becomes clear. By degrees eminentia granularis is getting unobvious existence, corpus cerebelli extends backward more or less and valvula cerebelli increases its capacity but is omnipresent in optic ventricle. At last the the outline of crista cerebelli is to be recognized and at the same time, saccus vasculosus will also make rapid progress. However, optic lobes keep hold the larges size, positive phototaxis is strong, and prey upon plankton in the near of the surface of the water.

In the second place, following the grope swimming life on the surface of the water, the stage gets into creeping action at times. The total length in this stage is 25 millimetres or so, in which medulla oblongata grows gradually, also

olfactory lobes make similar growth and saccus vasculosus is transformed into an adult fish. In an over-30mm-stage both outside shape and digestive canal are transformed into adult fish on the whole, change into omnivorous from plankton of bait and get into the depth swimming life from the group swimming life and at the same time, positive phototaxis is gradually ceased to exist.

More than two fissures appear of the backside of olfactory lobes as well as the projecting part olfactory lobes which is marked by goby family of fish would be formed and to become in the shape of adult fish generally. Other respective brain parts, on the other hand, are also transformed into the same shape in general.

Viewing from the point of ecological adaptation it goes into the deep swimming life in the stage of 40mm-total length. However, judging from the point of brain form, olfactory lobes are smaller than optic lobes.

On an average the growth medulla oblongata follows that of olfactory lobe but has not yet displayed a brain form of adult fish living in the depth of the water.

Summary

(1) Observed on the outside form of the brain and ecology which to transfome itself with the growth of *Chasmichthys gulosus* and investigated the relations between the two from the viewpoint of ontogeny.

(2) With respect to the brain form in swimming stage, both optic lobes and eminentia granularis are grown up well simultanecusly it has the brain form similar to the vasual fishes.

(3) Both telencephalon and medulla oblongata are keeping their growth in the brain form living in the depth of the water and goes into change of the gustatory and smell brain form.

(4) Immediately after incubation the nature of strong group living and positive phototaxis are going to move into negative phototaxis and not-in-group living little by little with a remarkable growth of olfactory lobes and medulla oblongata which would be seen in the swimming stage of total length 20 millimeters.

(5) Though in an aspect of growth in solid form both ecological adaptation and transformation of brain form are well-matched with each other, however, so far as time is concerned, it is the tendency of *Chasmichthys gulosus* that the former goes in advance of the latter.

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External Form of the Brain in Japanese Salmonoid Fishes and its Ecologieal Meaning

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and Osamu SANO*

One of the authors, UCHIHASHI (1953) has observed the external form of the brain in 72 Japanese teleosts species and noticed that the organ concerns intimately with the behaviour of fish. Since then, we have collected Japanese salmonoid fishes in various waters and studied external anatomy of the brain of these fishes in order to investigate the correlation between the external form of the brain and the behaviour.

Materials and methods

The fishes collected were fixed with 10% formalin and the brains dessected were fixed again with 10% formalin and their external character was observed by the aid of magnifying glass. Some samples were sectioned 20 μ in thickness and stained by the pal-weigelt double dying method for particular observation. (Table 1)

Table 1 Materials of study by forms and its locality of samplng. Identification of species follows MATSUBARA (1955); Species with ○ was studied previously by UCHIHASHI (1953) and in these with △ the section of the organ was made.

Genus	Remarks	Forms	Locality	Total length in cm. (Average)
Oncorhynchus		*O. nerka* (WALBAUM)	North Pacific Ocean	48.2
		O. gorbuscha (WALBAUM)	North Japan Sea	42.0
	○△	*O. keta* (WALBAUM)	Shinano River	51.3
		O. masou var. masou (BREVOORT)	North Pacific Ocean	40.8
	△	*O. masou var. ishikawae* (JORDAN *et* MCGREGOR)	Agano River	23.2
Salmo *Salvelinus*	○△	*S. gairdnerii irideus* GIBBONS	Tajima (cultured)	33.5
	△	*S. pluvius* (HILGENDORF)	Agano River	40.2
	△	*S. fontinalis fontinalis* (MITCHILL)	Shinano (cultured)	25.2

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Results of observation

Oncorhynchus nerka (WALBAM)

The fatty tissue covering the brain is considerably large in quantities and the brain as a whole is slightly depressed. The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is slightly slant forward, and the top of optic lobe is situated nearly on this line. The order of size of various parts of brain is as follows: 1) optic lobes 2) medulla oblongata 3) corpus cerebelli 4) olfactory bulbs plus olfactory lobes and 5) infundibulum plus inferior lobes.

Olfactory bulb, triangular shape in lateral view, is one half as long as olfactory lobe in size and joins closely with the latter, which is oval in form and is moderately developed, and its back side looks a triangular shallow hollow by the railing fissure limitans telencephali (KAPPERS, 1936). Fissura endorhinalis, Sulcus ypsiliformis and tuberculum taeniae are not clear.

Saccus dorsalis is not visible in external view, and epiphysis swelling in the front is comparatively large. Chiasma opticus is in a single cross, the right nerve cord over the left and these nerves are consisted of many small fiber bundles which show elliptic form in the cross section. Infundibulum lying rear of chiasma opticus is of small horseshoe form and covered with hypophysis which is very large and resembles a chestnut in shape. Sulcus recessus hypophysis is large in size. Inferior lobe small in size is thin and elliptic, but swells considerably, having a weak fovea nervi oculomotorii on the lateral side. Succus vasculosus, with a rather shallow groove, is of thin elliptic form and extends to the middle part of the median line between the inferior lobes in pair.

Optic lobe, growing larger posteriorly, has an elliptic form in dorsal view and "Lateralen Einschnurung" (LISSNER, 1923) is not perceivable, because both optic lobes extend to the side, a part of dorsal torus longitudinalis appearing between them.

Corpus cerebelli is large; lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a tang covers dorsal medulla oblongata. Valvula cerebelli which lies in the optic ventricle shows pattern of a stone-flooring (UCHIHASHI, 1953) as there are perceived 6 swells by fissure in its dorsal surface, and it is divided into anterior and posterior lobes laterally, and in the latter are observed still more 3 swelling portions. Eminentia granularis is ear-like and prominently swells.

Medulla oblongata is very large and the well developed crista cerebelli resembles a long bank, and ventriculus quartus is situated between them.
Both facial and vagal lobe are not noticed clearly but their parts where they locate are markedly swelled.

Oncorhynchus gorbuscha (WALBAUM)

The fatty tissue lying over the brain is considerably large in quantities and the brain as a whole is some what depressed. The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is slightly slant forward, and the top of optic lobe is situated nearly on this line. The order of size of various parts of brain is as follows: 1) optic lobes 2) medulla oblongata 3) corpus cerebelli 4) olfactory bulbs plus olfactory lobes and 5) inferior lobes plus infundibulum.

Olfactory bulb, triangular shape in lateral view, is two thirds as large sa olfactory lobe in size and joins closely with the latter, which is rice-like in form and is moderately developed, and its back side looks a triangular shallow hollow by the railing fissura limitans telencephali. Fissura endorhinalis, sulcus ypsiliformis and tuberculum taeniae are not clear.

Saccus dorsalis is small in size and epiphysis swelling in the front is comparatively large. Chiasma opticus is in a single cross, the left nerve cord over the right and these nerves show elliptic form in the cross section. Infundibu lum lying in rear of chiasma opticus is of considerably small horseshoe form and covered with hypophysis which is very large and looks like a globe. Sulcus recessus hypophysis is large in size. Inferior lobe small in size looks like a horseshoe in form but swells considerably, having a weak fovea nervi oculomotorii on the lateral side. Succus vasculosus, with a rather shallow groove, is of wheat shape and extends to the middle part of the median line between the inferior lobes in pair.

Optic lobe has an elliptic form in dorsal view and "Lateralen Einschnurung" is not pereceivable, because both optic lobes extend to the side, a part of dorsal torus longitudinalis observed between them.

Corpus cerebelli is large, lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a tang covers dorsal medulla oblongata. Valvula cerebelli shows a pattern of a stone-flooring as there are perceived 6 swells in the dorsal surface, and it is devided into anterior and posterior lobes laterally, and in the latter are observed still more 2 swelling portions. Eminentia granularis is ear-like and remarkably swells.

Medulla oblongata is very large and well developed crista cerebelli resembles a long bank, and ventriculus quartus is situated them. Both facial and vagal lobe are not discovered clearly but their parts where they locate are makedly swelled.

Oncorhynchus keta (WALBAUM)

The fatty tissue covering the brain is large in quantities and the brain as

a whole is slightly depressed. The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is slightly slant forward, and the top of optic lobe exists a little higher on this line. The order of size of various parts of brain is as follows: 1) optic lebes 2) medulla oblongata 3) corpus cerebelli 4) olfactory bulbs plus olfactory lobes and 5) infundibulum plus inferior lobes.

Olfactory bulb, dull trianglar shape in lateral view, is two thirds as large as olfactory lobe in size and joins closely with the latter, which is ellipse in form and is moderately developed, and its back side looks a triangular shallow hollow by the railing fissura limitans telencephali. Fissura endorhinalis, sulcus ypsiiformis and tuberculum taeniae are not cleare.

Saccus dorsalis is small and epiphysis swelling in the front is considerably large. Chiasma opticus is in a single cross, the right nerve cord over the left and these nerves are consisted of many small fiber bundles which show obtuse elliptic form in the cross section. Infundibulum lying in rear of chiasma opticus is of small heart shape and covered with hypophysis which is very large and thick and resembles a chestnut. Inferior lobe moderate in size is of elliptic form but swells considerably, having a weak fovea nervi oculomorii on the lateral side. Succus vasculosus with a rather shallow groove, is of wheat shape and extends to the middle part of the median line between the inferior lobes in pair.

Optic lobe has a long elliptic form in dorsal view and "Lateralen Einschnurung" is not perceivable, because both optic lobes extend to the side, a part of dorsal torus longitudinalis seen between them.

Corpus cerebelli is large, lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a tang covers dorsal medulla oblongata. Valvula cerebelli shows a pattern of a stone-flooring as there are 6 swells in its dorsal surface and it is divided in to anterior and posterior lobes laterally, and in the latter are observed still more 2 swelling portions. Eminentia granularis is of elliptic form and markedly swells.

Medulla oblongata is very large and well developed crista cerebelli resembles a long bank, and ventriclus quartus is situated between them. Facial and vagal lobe are not noticed clearly but their parts where they locate are markedly swelled.

Oncorhynchus masou var. masou (BREVOORT)

The fatty tissue covering the brain is large in quantities and the brain as a whole is slightly depressed. The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is slightly slant forward, and the top of optic lobe is situated neraly on this line. The order of size of various parts of brain is as follows: 1) optic lobes 2) medulla oblogata 3) corpus cerebelli 4)

olfactory lobes plus olfactory bulbs and 5) inferior lobes plus infundibulum.

Olfactory bulb, triangular shape in lateral view, is two thirds as large as olfactory lobe in size and joins closely with the latter, which is rice-like in form and is moderately developed, and its back side looks a triangular shallow hollow by the fissura limitans telencephali. Fissura endorhinalis, sulcus ypsiliformis and tuberculum taeniae are not clear.

Saccus dorsalis is not visible in external view, and epiphysis swelling in the front is comparatively large. Chiasma opticus is in a single cross, the left nerve cord over the right and these nerves show elliptic form in the cross section. Infundibulum lying in front of chiasma opticus is of medium horseshoe-like form and covered with hypophysis which is very large and resembles a cone in shape. Sulcus recessus hypophysis is large in size. Inferior lobe, small in size is elliptic, but swells considerably, having a weak fovea nervi oculomotorii on the lateral side. Saccus vasculosus, with a rather shallow fissure, is of elliptic form and extends to the middle part of the median line between the inferior lobes in pair.

Optic lobe has an egg-like form in dorsal view and "Lateralen Einschnurung" is not perceivable, because both optic lobes extend to the side, a part of dorsal torus longitudinalis appearing between them.

Corpus cerebelli is large, lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a slender tang covers dorsal medulla oblongata. Valvula cerebelli presents a stone-flooring look. There are perceived 6 swells in its dorsal surface, and in lateral view it is divided into anterior and posterior lobes, and in the latter are observed still more 2 swelling portions. Eminentia granularis is oval form and markdly swells.

Medulla oblongata is large and the well develped crista cerebelli resembles a long bank, and ventriculus quartus is situated between them. Facial and vagal lobe are not noticed clearly but their parts where they locate are markedly swelled.

Oncorhynchus masou var. ishikawae (JOLDAN et Mc GREGOR)

The fatty tissue covering the brain is moderate in quantities and the brain form is a little depressed. External form of this brain almost resembles to that of *Oncorhynchus masou var. masou.* The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is slightly slant forward, and the top of optic lobe is situated nearly on this line. The order of size of various parts of brain is as follows: 1) optic lobes 2) medulla oblongata 3) corpus cerelli 4) olfactory bulbs plus olfactory lobes and 5) infundibulum plus inferior lobes.

Olfactory bulb, triangular shape in lateral view, is one half as large as olfactory lobes and joins closely to the latter, which is thin ellipse in form and is

somewhat small, and its back side looks a triangular shallow hollow by the fissura limitans telencephali. Fissura endorhinalis sulcus ypsiliformis and tuberculum taeniae not clear.

Saccus dorsalis is not visible in external view, and epiphysis swelling in the front is comparatively large. Chiasma opticus is in a single cross, the right nerve cord over the left and is of a round shape in the cross section. Infundibulum is moderate in size and like a heart in form and covered with hypophysis which is very large and resembles a ball in shape. Sulcus recessus hypophysis is medium in size. Inferior lobe small in size is of thin and elliptic having a weak fovea nervi oculomotorii on the upper side. Saccus vasculosus, with a weak shallow groove, is of square shape and does not reach the middle part of the median line between the inferior lobes in pair.

Optic lobe is of oval and "Lateralen Einschnurung" is not conscious, and as the both optic lobes extend to the side, a part of dorsal torus longitudinalis is seen between them.

Corpus cerebelli is large, lobus anterior cerebelli is not perceivable and lobus posterior cerebelli stretching out backward like a tang covers dorsal medulla oblongata. Valvula cerebelli presents a stone-flooring look as there are perceived 6 swells in its dorsal sarface, and it is divided into anterior and posterior lobes laterally, and in the latter are considered to be present still more 3 swelling portions. Eminentia granularis is oval and large swells.

Medulla oblongata is considerably large and the well developed crista cerebelli resembles a long bank, and ventriculus quartus is placed between them. Facial and vagal lobe are not observed in external view but their parts where they locate are markedly swelled.

Salmo gairdnerii irideus GIBONS

The fatty tissue lying upon the brain is of very small quantities and the brain as a whole is a little depressed. The slope of the line joinning the top of olfactory lobe with that of corpus cerebelli is slightly slant forward, and the top of optic lobe is placed nearly on this line. The order of size of various parts of brain is as follows: 1) optic lobes 2) medulla oblongata 3) corpus cerebelli 4) olfactory bulbs plus olfactory lobes and 5) infundibulum plus inferior lobes.

Olfactory bulb, triangular form in lateral view, is one half as large as olfactory lobe and joins closely with the latter, which is of thin elliptic form and is moderately developed, and its back side looks a triangular shallow hollow by the fissura limitans telencephali. Fissura endorhinalis, sulcus ypsiliformis and tuberculum taeniae are not clear.

Saccus dorsalis is not visible in external view and epiphysis swelling in the front is large. Chiasma opticus is in a single cross, the right nerve cord over

the left one and these nerves show elliptic form in the cross section. Infundibulum lying in rear of chiasma opticus is of medium heart-like form and covered with hypophysis which is very large and resembles a chstnut in shape. Sulcus recessus hypophysis is large in size. Inferior lobe small in size is pillow-like form (UCHIHASHI 1953) but swells considerably, having a weak fovea nervi oculomotorii on the upper side. Saccus vasculosus, with a small shallow groove, is of thin elliptic form and extends to the middle part of the median line between the inferior lobes in pair, but many vacuoles exist in it.

Optic lobe has on elliptic form in dorsal view and "Lateralen Einschnurung" is not perceivable. Both optic lobes extend to the side, and part of dorsal torus longitudinalis is observed between them.

Corpus cerebelli is large, lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a tang covers dorsal medulla oblongata. Valvula cerebelli shows pattern of a stone-flooring as there are perceived 8 swells by fissure in dorsal surface and it is divided still more 4 swelling portions. Eminentia granularis is ear-like and is moderately developed.

Medulla oblongata is large and the well developed crista cerebelli which shows a bank form is placed outside of ventriculus quartus. Facial and vagal lobe are not observed in the external look but their parts where they locate are markedly swelled.

Salverinus pluvius (HILGENDORF)

The fatty tissue covering the brain is a little in quantities and the brain as a whole is a little depressed. The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is a little slant forward, and the top of optic lobe juts out slightly. The order of size of brain parts in out look is: 1) optic lobes 2) medulla oblongata 3) corpus cerebelli 4) olfactory bulbs plus olfactory lobes and 5) infundibulum plus inferior lobes.

Olfactory bulb, obtuse triangular shape in lateral view, is one half as long as olfactory lobe in size and joins closely with the latter, which is thin ellipse in form and is somewhat small, and its back side looks a triangular shallow hollow by the railing fissura limitans telencephali. Fissura endorhinalis, sulcus ypsiliformis and tuberculum taeniae are not clear.

Saccus dorsalis is not visible in external view, and epiphysis swelling in the front is comparatively large. Chiasma opticus is in a single cross, the right nerve cord over the left and shows an elliptic shape in the cross section. Infundibulum is moderate in size, is like heart in form and covered with hypophysis which is very large and looks like an ellipse. Sulcus recessus hypophysis is medium in size. Inferior lobe is small in size is elliptic, having a weak fovea nervi oculomotorii on the lateral side. Saccus vasculosus, with a weak shallow

groove, is of oval shape and does not extends to the middle part of the median line between the inferior lobes in pair.

Optic lobe is of thin elliptic form and "Lateralen Einschnurung" is not censcious. As the optic lobes extend to the side, a part of dorsal torus longitudinalis is appeared between them.

Corpus cerebelli is large, lobus anterior cerebelli is not perceivable and lobus posterior cerebelli stretching out backward like a tang covers dorsal medulla oblongata. Valvula ceredelli presents a stone-flooring look as there are considered to be present still more 6 swells in dorsal view, and it is divided into anterior and posterior lobes laterally, and in the latter there are 3 swelling portions. Eminentia granularis is ellipse in form and prominently swells.

Medulla oblongata is considerably large and the well developed crista cerebelli resembles a long bank, and ventriculus quartus is placed between them. Facial and vagal lobe are not visibled in external view but their parts where locate are markedly swelled.

Salvelinus fontinalis fontinalis (MITCHILL)

The fatty tissue covering the brain is of a small quantities and the brain form is a little depressed. The slope of the line connecting the top of olfactory lobe with that of corpus cerebelli is a little slant forward, and that top of optic lobe juts out slightly on this line. The order of size of brain parts is: 1) optic lobes 2) medulla oblongata 3) corpus cerebelli 4) olfactory bulbs plus olfactory lobes and 5) iofundibulum plus inferior lobes.

Olfactory bulb, triangular shape in lateral view, half as long as olfactory lobe in size and is connected closely with the latter, which is ellipse in form and is moderately developed, and its back side looks a triangular shallow hollow by the fissura limitans telencephali. Fissura endorhinalis, sulcus ypsiliformis and tuberculum taeniae are not discovered.

Saccus dorsalis is not clear in external view, and epiphysis swelling in the front is comparatively large. Chiasma opticus is in a single cross, the right nerve cord over the left and these nerve show round shape in the cross section. Infundibulum lying in rear of chiasma opticus is of medium horseshoe form and covered with hypophysis which is somewhat small. Sulcus recessus hypophysis is large in size. Inferior lobe medium in size is elliptic, but swells considerably, having a weak fovea nervi oculomotorii on the lateral side. Saccus vasculosus, with a rather shallow groove, is of raindrop form and extends to the middle point of the median line between the inferiof lobes in pair.

Optic lobe is of an elliptic form in dorsal view and "Lateralen Einschnurung" is not perceivable, because both optic lobes extend to the side, a part of dorsal torus longitudinalis appearing between them.

Corpus cerebelli is large; lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a tang covers dorsal medulla oblongata. Valvula cerebelli which lies in the optic ventricle shows pattern of a stone-flooring as there are perceived 6 swells in its dorsal surface, and it is devided into anterior and posterior lobes laterally, and in the latter observed still more 2 swelling portions. Eminentia granularis is ear-like and large swells.

Medulla oblongata is very large and the well developed crista cerebelli resembles a long bank, and ventriculus quartus is situated between them. Facial and vagal lobe are not noticed clearly but their parts where they locate are markedly swelled.

The external form of brain and the behaviour in salmonoid fishes

1) Cranial cavity and volume of the brain

The volume of the brain which occupies the cranial cavity in teleosts various greatly by species and this fact arises from the quantity of fatty tissue covering the brain. One of the authors, UCHIHASHI (1953) has examined the fatty tissue in cranial cavity of some fishes and stated that it is in close relation with the depth of water they dwell, and a remarkable growth in fatty tissue is discoverd among the fishes living in the greater depth of the sea, further the tracing of the development of teleost brain revealed the fact that its volume changes during the growth of fish within a species.

The salmonoid fishes are in general classified into the groups with medium and lesser quantities in fatty tissue (UCHIHASHI, 1953), more over precise observation, in this group are observed still more two sub-groups, i.e., the subgroup with higher quantity of fatty tissue, (*Oncorhynchus nerka*, *Oncorhynchus gorbuscha*, *Oncorhynchus keta* and *Oncorhynchus masou var. masou*) and the sub-group with lesser quantity of fatty tissue, (*Oncorhynchus masou var. ishikawae*, *Salmo gaidnerii irideus*, *Salvelinus pluvius* and *Salvelinus fontinalis*).

According to the ecological observation in salmon, the former includes oceanic species and the latter fresh water fishes, and this fact seems to agree well with the opinion of UCHIHASHI (1953) above-mentioned. Especially, the fact that the volume of fatty tissue in *Oncorhynchus masou var. masou* is larger in quantities than that in *Oncorhynchus masou var. ishikawae*, the land-locked form of the former, can be considered to correspond to the difference in the behaviour and habitat.

2) Type of the brain

The brain in 8 forms of salmonoid fishes we have examined are slightly depressed and accords with morphnlogical character of brain in the surface fishes (UCHIHASHI, 1953).

3) The degree of development in each part of the brain

Table 2. External characters of brain in eight species of salmonoid fish.

Parts		Fatty tissue	Order in size of various part of brain	T-C line		Lateral view
Genous	forms			Slope	Situation of optic lobes	Olfactory bulb
Onco-rhynchus	*O. nerka*	much quantity	O-M-C-T-D	a little slant forword	on T-C line	trianglar
〃	*O. gorbuscha*	〃	〃	〃	〃	〃
〃	*O. keta*	〃	〃	〃	a little higher than T-C line	〃
〃	*O. masou val. masou*	〃	〃	〃	on T-C line	〃
〃	*O. masou val. ishika-wae*	medium quantity	〃	〃	〃	〃
Salmo	*S. gaird-nerri irid-eus*	a very little quantity	〃	〃	〃	〃
Salvelinus	*S. pluvius*	a little quantity	〃	〃	jut out from T-C line	〃
〃	*S. fontinalis fontinalis*	〃	〃	〃	〃	〃

T-C line ……The line connecting the top of olfactory lobe with that of corpus cerebelli

O……Optic lobes

M……Medulla oblongata

C……Cerebellum

T……Olfactory bulbs plus olfactory lobes

D……Inferior lobes plus infundibulum

(See foot-note for the definition abbreviated letters in table).

Dorsal view			
Olfactory lobe	Optic lobe	Corpus cerebelli and eminentia granularis	Valvula cerebelli
ellipse	thin ellipse		
thin ellipse	ellipse		
ellipse	thin ellipse		
rice-like	oval		
thin ellipse	〃		
〃	ellipse		
〃	thin ellipse		
ellipse	oval		

According to the result of comparative investigation on the development of the various parts of brain (telencephalon, mesencephalon, diencephalon and medulla oblongata etc.), the salmonoid fishes are believed to belong to the category carrying in mesencephalon well-grown as UCHIHASHI has mentioned (1953). The species which has a well developed mesencephalon is found among many teleosts, and these 8 forms of salmons have medulla oblongata second in order of size followed by large cerebellum among 5 parts of brain (Table 2). As will be mentioned later, the fact that the medulla oblongata is considerably well de veloped in spite of the absence of prominent swells in crista cerebelli may show the gastatory sence highly inportant to these fishes among other function in mode of life.

4) Telencephalon

A) Olfactory bulb

In all species examined, the olfactory bulbs combine closely with olfactory lobes and olfactory region joins with the former by long olfactory nerves. According to UCHIHASHI (1953), the degree of the olfactory faculties in fishes has an intimate relation with the developments not only in olfactory lobes but also in olfactory bulbs. The fishes in this family have a well developed olfactory bulbs which are of triangular shape in lateral view, and it is significant to see that *Oncorhynchus gorbuscha, Oncorhynchus keta* and *Oncorhynchus masou var. masou* have large bulbs compared with the olfactory lobes, and the former are two thirds as large as the latter in size.

B) Olfactory lobe

The size and shape of the olfactory lobes which occupy the main portion of telencephalon vary forms. The organ in salmonoid fishes are simple comparatively and divided clearly into two hemisphers, further some species have olfactory lobes consisted of small epistrata and large substrata on the whole these strata not clearly observed. The back side olfactory lobes in all species of salmon shows a triangular shallow hollow formed by fissura limitans telencephalli, and fissura endorhinalis, sulcus ypsiliformis, tuberculum taeniae are not discovered in these species. However, the fact that olfactory bulbs comparatively well develop an mentioned above and that olfactory lobes are comparatively large (especially in oceanic salmon) are leading to interpret they depending upon the olfactory sence more than in other surface fishes such as mackerels, sardines, and etc.. Moreover, that the homing instinct or orientation in salmon is attributed to smell sense (HASLAR, 1954, 1955) and that recently *Oncorhynchus gorbuscha* is frequently fished in Hokkaido by long line during the night (NIWA, 1955) may be due to the structures of telencephalon and medulla oblongata as will be referred later.

5) Diencephalon

A) Saccus dorsalis

The tiny saccus dorsalis is discovered in *Oncorhynchus gorbuscha* and *Oncorhynchus keta* but in other species it is difficult to find with our naked eye and its ecological meaning is not understood at presents.

B) Epiphysis

The epiphysis of all these species developes well, and swells in the top, in some species extending to near the olfactory bulb. Reciprocity between this organ and the behaviour is not understood clearly.

C) Saccus vasculosus

Saccus vasculosus is classified to the type of thin elliptic form (as in *Oncorhynchus nerka* and *Salmo irideus*) and that of wedge (*Oncorhynchus gorbuscha* and *Oncorhynchus keta*) or that of square (*Oncorhynchus masou var. ishikawae*) or that of oval (*Oncorhynchus masou var. masou* and *Salvelinus pluvius*) or that of raindrop (*Salvelinus fontinalis*), and all species have longitudinal shallow on the ventral surface. In external view, *Oncorhynchus nerka*, *Oncorhynchus keta* and *Salmo irideus* have a large saccus vasculosus, *Oncorhynchus gorbuscha* and *Oncorhynchus masou var. masou* a considerably large one, *Salvelinus fontinalis* a moderate and *Oncorhynchus masou var. ishikawae* and *Salvelinus pluvius* a small one. In general oceanic salmons are inclined to have a large saccus vascalosus. In *Salmo irideus*, saccus vasculosus is large in size but many vacuoles exist in it. UCHIHASHI (1953) has noticed that in the teleosts the size and shape of succus vasculosus and their havitual water have an established interrelation, and this is the organ that has been stated, according to KAPPERS (1936), by some authors including BOEKE (1901), JHONSTON (1906) and DAMMERMAN (1910) probably to serve forthe perception of fluid pressure and, the perception of depth since the pressure increases with the depth of water. As mentioned above in salmonoid fishes, saccus vasculosus of landlocked and fresh water forms is either very small in size or not solid as compared with that of oceanic fishes and these facts show that progress of this organ has accordance with the behaviour. Especially, it is interesting to note that saccus vasculosus of *Oncorhynchus masou var. masou* is more progressed than that of *Oncorhynchus masou var. ishikawae*, the landlocked-form of the former, also that the above-mentioned relationship between the quantity of fatty tissue and the ocean-going habit is also applicable to these forms.

D) Infundibulum

Infudibulum is an organ which is most remarkably swollen in the ventral portion of diencephalon. In salmon these are covered with large hypophysis and are horseshoe, heart, or ellipse in form and sulcus recessus hypophysis is recognized on them. It is smaller than inferior lobe in size and its connection with the behaviour is not clear.

E) Inferior lobe

In salmonoid fishes, inferior lobes are of elliptic or pillow-like form and are small in size, but they swell considerably having a weak fovea nervi oculomotorii on the lateral side. The degree of growth and swelling the inferior lobe has a positive correlation with the behaviour in the nocturnal fish (UCHIHASHI, 1953), and in these salmonoid forms inferior lobe is medium or small in size but swells comparatively in form, differing form that of surface fishes. Therefore, the salmonoid fishes do not seem to carry on feeding on purely visual sence.

6) Mesencephalon (Optic lobes)

In teleost there are many species which have the well developd optic lobes. These salmonoid fishes, however, entirely lack them but the optic lobes are developd more remarkably than other parts of the brain and are thin-ellipse, oval or ellipse in form and show some features charactaristic to salmon, that is, the optic lobes extends to the side, a part of dorsal torus longitudinalis seen between them. By the reasons of the charactaristic of optic lobes in these fishes and of their behaviour to bite feather hook, *Oncorhynchus masou var. masou*, *Oncorhynchus masou var. ishikawae*, *Salmo irideus*, *Salverinus pluvius* and *Salverinus fontinalis* seem to have a visual perseption for feeding. And other salmons such as *Oncorhynchus keta*, *Oncorhynchus nerka* and etc. may also be fished by the same method, but we have not yet heard they actually are.

7) Cerebellum

A) Corpus cerebelli

Corpus cerebelli in these fish is classified as "large bend backward type" (UCHIHASHI, 1953), lobus anterior cerebelli is not clearly seen and lobus posterior cerebelli extending backward like a tang covers all of ventriclus quartus, and exsits a big longitudinal riseing on that.

The degree of development of this organ is said to be related to speed and ability of swimming and to balance of body (TUGE, 1934, UCHIHASHI, 1952, 1953). Therefore that the corpus cerebelli is large in salmonoid fishes seem to agree the behaviour of thses fishes which are wide-range migrators.

In the dark *Salmo irideus* stays still in some position and seems to keep the balance of body facing forward the water flow (UCHIHASHI, TUGE, INOUE and II, 1954). *Salverinus fontinalis*, *Oncorhynchus masou var. ishikawae* also seem to have a similar behaviour, and oceanic salmon such as *Oncorhynchus keta*, *Oncorhynchus gorbuscha*, *Oncorhynchus masou var. masou* should have the same behaviour judging from our observation on corpus cerebelli.

B) Valvula cerebelli

Valvula cerebelli is a part of the cerebellum which extends in optic ventricle, but not found externally. Its function and structure have been described by UCHIHASHI (1953) who stated that the size which occupies on optic ventriclus

has relation to the behaviour of the species, that is, the larger in size and the more complicated in structure the quicker in the swimming. So far as the 8 forms in salmon are concerned this organ occupies more than half of area in optic ventriclus and appears like a stone-flooring and is divided into two portions, anterior and posterior lobe. In the latter are observed more than 4 to 6 portions by which we can classify them into some refferent groups, also the structure of valvula cerebelli in these fishes shows the characteristic of the behaviour which is quick in action.

C) Eminentia granularis

In salmonoid fishes the eminentia granularis which are swelled into a lump is ear-like in shape (*Oncorhynchus nerka, Oncorhynchus gorbuscha, Salmo irideus* and *Salvelinus fontinalis*), ellipsoid (*Oncorhynchus keta* and *Salvelinus pluvius*) and oval (*Oncorhynchus masou var. masou* and *Oncorhynchus masou var. ishikawae*) in form, and is more or less larger in size as compared with that in other fishes. This organ substitutes functionally for auricles (KAPPERS, 1936) and is important organ in sense of equilibraium and together with lateral line (UCHIHASHI, 1953). The fact that salmonoid fishes have a well developed eminentia granularis agrees with their behaviour which is categoristed as surface swimmer.

7) Medulla oblongata

A) Crista cerebelli

In salmonoid fishes the crista cerebelli well-developing resembles a long bank and ventriclus quartus is situated between them but develops in a poorer degree compered with other members in the group with a prominently developed crista cerebelli which looks like a bridge. The development of crista cerebelli is stated by KAPPERS (1936) to have connection with the great development of lateral line system. Those fishes depend not only on the visual sense for the forming of school but also the lateral line system when schooling is made at night by feeling the wave of vibration caused by swimming (UCHIHASHI, 1953). Therefore the development of crista cerebelli has reciprocity to schooling behaviour at night.

According to these views the fishes in Genus *Oncorhynchus* seem to have some schooling behaviour which, however, is not considered to prevail in a same degree as in other pelagic fishes. In fact, in these fishes the nocturnal schooling is not found clearly at night.

B) Facial and vagal lobes

Facial and vagal lobes are not clearly visible externally but their places are well swollen as compared with other surface fishes such as yellowtail, fanacuda and mackerel. The fact that these species are fished by long line at night or in the daybreak (SOEDA, 1954) show relation to the development of gustatory sense organ in medulla.

Summary

The external character of the brain was observed in 8 forms of salmonoid fishes and its relation to the behaviour was discussed.

1) The morphological characteristics of the brain may be briefed as follows:

A) Concerning the fatty tissue the fishes are classified into a group with medium amount and other with lesser amount; each group is further subdivided into sub-group, with higher quantity of fatty tissue and the sub-group, with lesser quantity of fatty tissue.

B) The brain is slightly depressed, and the slope of the line connecting the top of olfactory lobe with the same of corpus cerebelli is slightly inclined anteriorly.

C) Olfactory lobes join closely to the front of olfactory lobes and they are the largest among fishes of surface water or of migratory behavior. Olfactory lobes have a fissura limitance telencephali on its dorsal surface.

D) Inferior lobes, rather small ellipsoid and swell considerably carring weak fovea nervi oculomotorii. Saccus vasculosus is horseshoe, heart or oval in shape.

E) Optic lobes are a little smaller than in other surface fish. Torus longitudinalis is seen between the rear part of dorsal optic lobes.

F) Corpus cerebelli is large in size. Lobus anterior cerebelli is not clearly seen, and lobus posterior cerebelli, tang like, covers all surface of ventriclus quartus; valvula cerebelli resembles stone-pavement in appearance. Eminentia granularis swells to an ellipsoid or oval body.

G) Crista cerebelli, well developed, appears in an elongated bank. Externally facial and vagal lobes are not visible, but their location is discernible by swelling on the surface.

2) External character of brain and the behaviour of fish may be summarised;

A) The fact that telencephalon is moderately developed and inferior lobes are small but swell comparatively well in the salmonoid fish will lead us to believe these fish depending in greater extent on olfactory sense than other surface or migrating species such as sardine, mackerel, Pacific saury and etc.

B) The size of saccus vasculosus in the salmonoid fish has cleary shown to very relating to the behaviour of fish observed in sea-going, land-lock or freshwater life.

C) The fact that crista cerebelli is well developed but in a poorer degree as compared with those members in the group of prominent development asdefined

by UCHIHASHI (1953) and that it does not show the bridge-form (UCHIHASHI 1953) gives rise to question to the prominent schooling habit refered to these fishes, the habit which is though considered to be somewhat comparatively intensified by progress of lateral line sense.

D) In shape and size valvula cerebelli varies by forms to the salmonoid fish and its development appears to bear a relation to the speed of fish in movement.

We wish here to express our deep thanks to messrs. Dr. K. Kuronuma (Tokyo), M. Amano (Niigata), H. Fukataki (Niigata), I, Oya (Hokkaido) and Miss A. Honda (Niigata).

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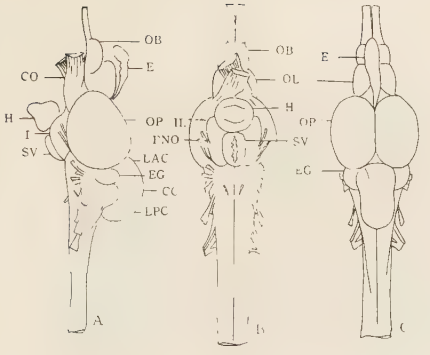
Plate 1. The external form of brain in salmonoid fishes.

A) Lateral view, B) Ventral view, C) Dorsal view

1.	*Oncorhynchus nerka*	1.4×
2.	*Oncorhynchus gorbuscha*	1.4×
3.	*Oncorhynchus keta*	1.6×
4.	*Oncorhynchus masou var. masou*	1.6×
5.	*Oncorhynchus masou var. ishikawae*	2.8×
6.	*Salmo gaidnerii irideus*	2.0×
7.	*Salvelinus pluvius*	1.6×
8.	*Salvelinus fontinalis fontinalis*	2.8×

Abbreviations used in the explanation of figures:

CO, Chiasma opticum. CC, Corpus cerebelli. EG, Eminentia granularis. E, Epiphysis. FNO, Fovea nervi Oculomotorii. H, Hypophysis. IL Inferior lobe. I, Infundibulum. LAC, Lobus anterior cerebelli. LPC, Lobus posterior cerebelli. OB, Olfactory bulb. OL, Olfactory lobe. OP, Optic lobe. SV, Saccus vasculosus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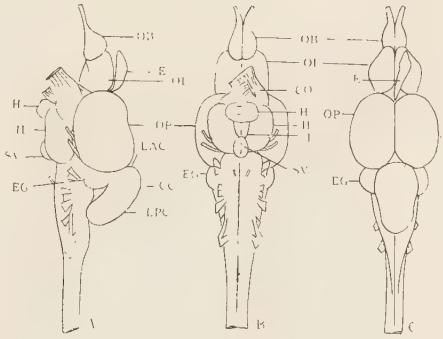
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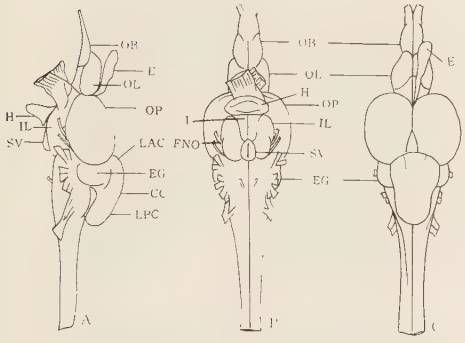
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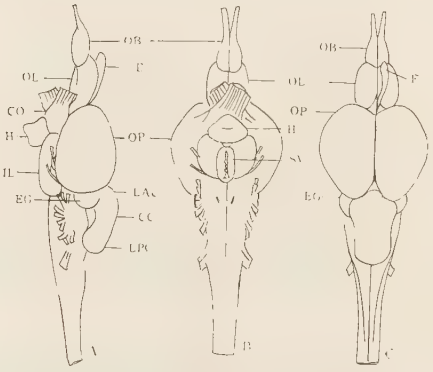
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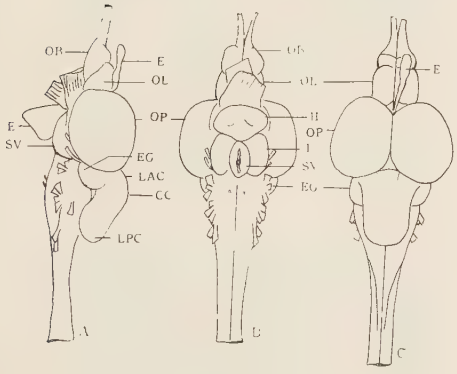
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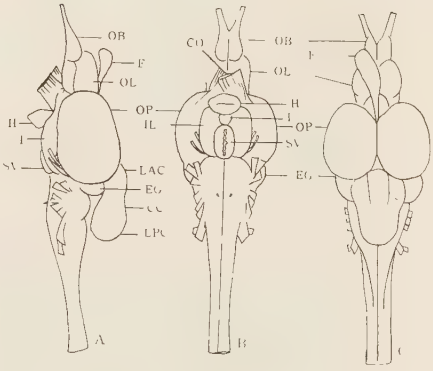
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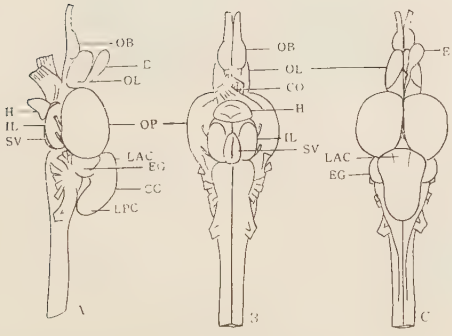
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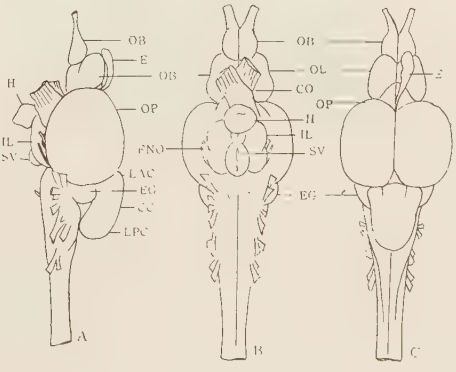
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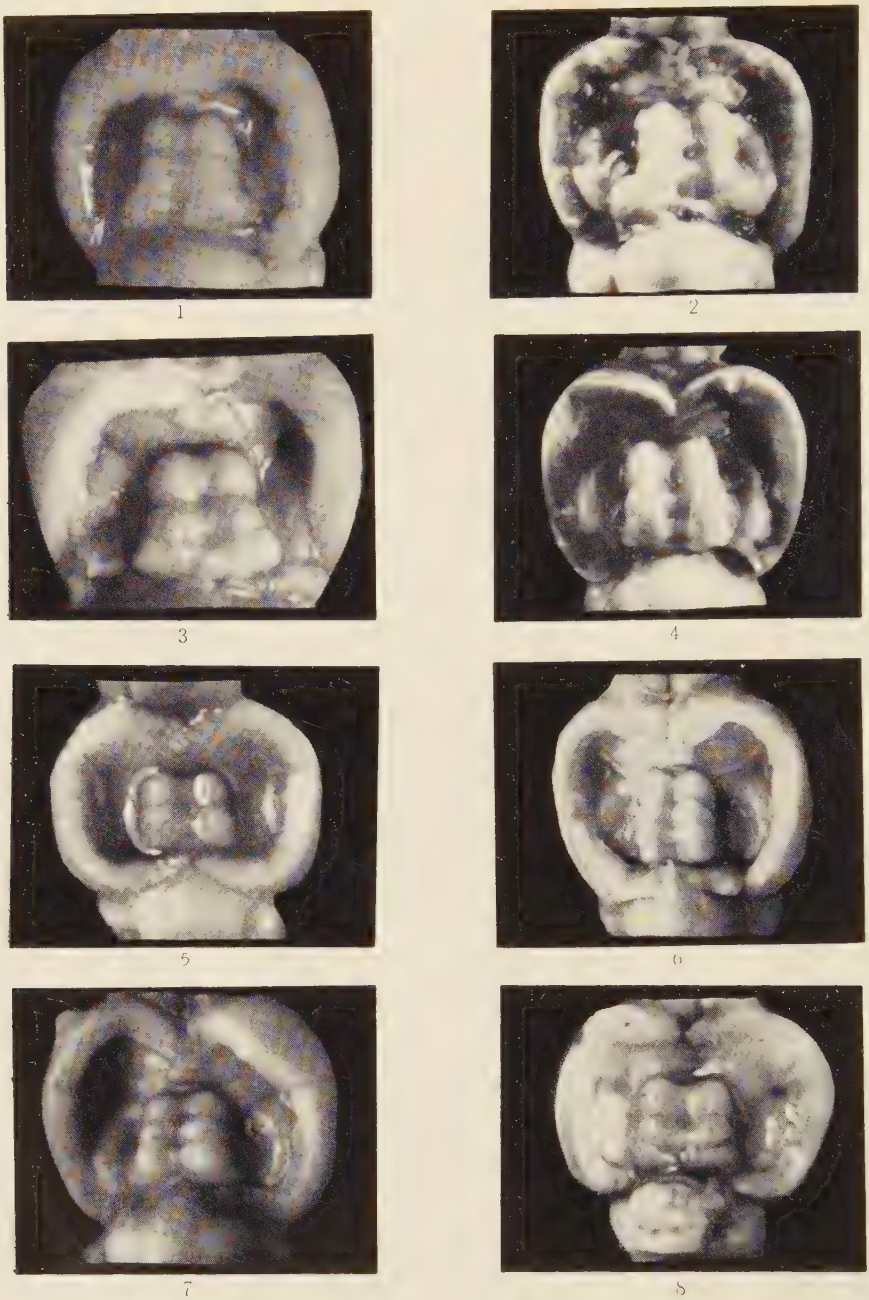

Plate 2. Dorsal view of valvula cerebelli in salmonoid fishes

1. *Oncorhynchus nerka* 4.0 ×
2. *Oncorhynchus gorbscha* 3.5 ×
3. *Oncorhynchus keta* 4.4 ×
4. *Oncorhynchus masou var. masou* 3.7 ×
5. *Oncorhynchus masou var. ishikawae* 4.5 ×
6. *Salmo gairdnerii irideus* 3.4 ×
7. *Salvelinus pluvius* 3.6 ×
8. *Salvelinus fontinalis* 4.2 ×

ズワイガニ *Chionoecetes opilio* の腹及び脚長節の相対成長とその段階について

伊　藤　勝千代

On the relative growth of abdomen and five paired thoracic appendages of Zuwaigani, *Chionoecetes opilio*

By

Katsuchiyo ITO

Chionoecetes opilio O. FABRICIUS, is one of the most important resourecs for trawl fishery in the western region of the Japan Sea.

The present paper deals with studies on the relative growth of the 3rd & 5th abdominal segments and of five thoracic appendages to the carapace width in this crab, the results being obtained as follows:

1) The metamorphosis of abdominal segments was observed to occur in females only and hereby they were able to be distinguished into following three types.

a. Young form (no more than 30mm in carapace width)
b. Immature form (30 to 50mm in carapace width)
c. Adult form (after ripeness of ovary)

2) The relative growth rate of thoracic appendages changes abruptly at the stage of about 30mm in carapace width in female and of about 70mm in male.

3) In male adult crabs more than 70mm in carapace width, there were two groups, the cheliped of which has different growth rate.

I　緒　　言

カニ類は一般に変態をおこない Nauplius 期，Zoea 期及び Megalopa 期を経て成体に達する。伊藤隆（'53）は糠脚類で，成長に伴う形態変化について，形態の質的変化及びその量的変化（相対成長）の詳細な研究をおこなつている。カニ類※ではケガニ（丸川安成'31）の研究があるが，形態変化について観察しただけで，それの量的変化の研究はまだないようである。

ズワイガニについては筆者（'56）が，成長過程における稚仔期以降の雌の腹部形態の変化をごく簡単に

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* 真正蟹類外ではタラバガニ，ハナサキガニ等の研究がある。

述べているにすぎず，成長段階による形態変化の過程についてはほとんど明らかにされていない。

その後，稚仔以降の成長に伴う形態変化について2，3の知見を得たので，とくに第2次性徴と重要な関係にある腹部の形態形成とその相対成長及び松浦（'54）が述べている“第2歩脚長節が甲巾 60mm 以上の雌ガニでは，長節/甲巾の比率の縮少が見られるのではないか”という点と，この現象がズワイガニの自然集団に，一般に見られるものであるかどうかを確めるために調査した脚長節の相対成長とについて述べる。

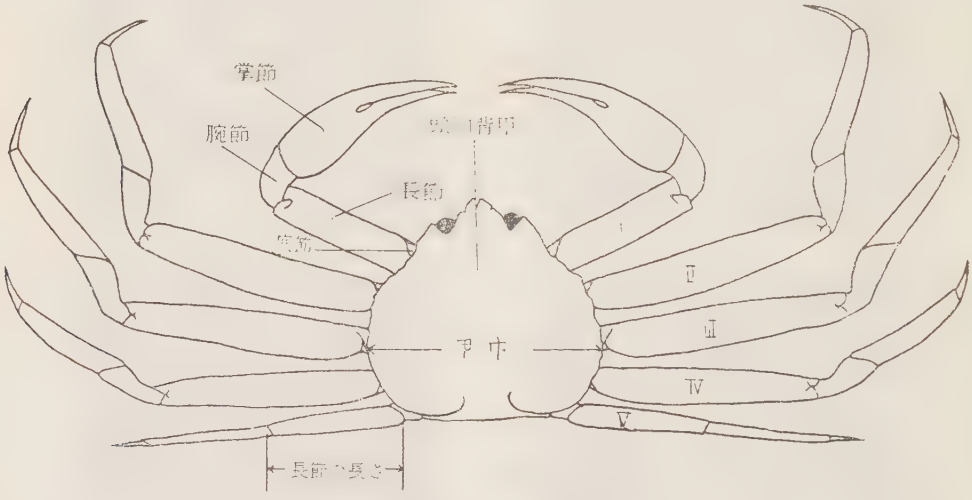
本論に先立つて，本研究の機会を与えられ，常々御指導と本文の御校閲を賜つた日本海区水産研究所長内橋潔博士，同資源部長加藤源治技官，また，平素御支援を賜つている香住支所長平井正夫技官，本文をとりまとめるにあたり種々討議くださつた小川良徳技官，渡辺徹技官の諸氏に衷心より謝意を表したいと思う。

Ⅱ　測定部位並びに測定方法

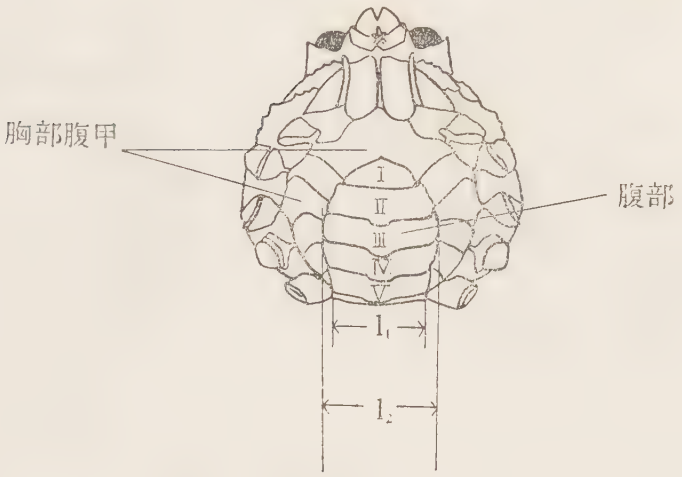
腹部：　まず頭胸部背甲の最大巾部（以下これを甲巾と称する）を測定し，腹部（第1図—B）は，第6腹節及び第3腹節の最大巾部を各々 l_1, l_2 とし，甲巾はノギス，腹節の巾は Divider で計測した。

脚長節：　甲巾とともに，鉗脚及び第1～4各歩脚の5対脚，計10脚について長節の長さを測定した。各長節の長さ（第1図—A）は，頭胸部背甲側にあたるそれぞれの最長部分とし，その計測には Divider を用いた

また，カニ類の対脚は同長と見なすことができるが，再生や自切などによつて対脚にいちぢるしい長短が生じたもの，あるいは漁獲時の処理などにより，対脚の一方が脱落したものなどは，とりまとめの際にその脚だけ除外した。したがつて，材料の項で述べる調査数と脚数とは必ずしも一致していない。



第1図　測定部位
(A)　頭脳部背面
Ⅰ　鉗脚
Ⅱ　第1歩脚
Ⅲ　第2部脚
Ⅳ　第3部脚
Ⅴ　第4部脚



(B) 同 腹 面（但し，脚を除いて示した）

I 第 1 腹 節
II 第 2 腹 節
III 第 3 腹 節
IV 第 4 腹 節
V 第 5 腹 節

III 研究結果並びに考察

(1) 腹部の相対成長

材料　供試材料は香住港の底曳漁船により，鳥取県賀露沖（農林29海区，水深 2[illegible] ～25[illegible] m）から漁獲したものを，1955年1～3月の期間内に4回の採集をおこない，総計288尾，うち，雌173尾（未熟123尾，，成熟50尾），雄115尾である。

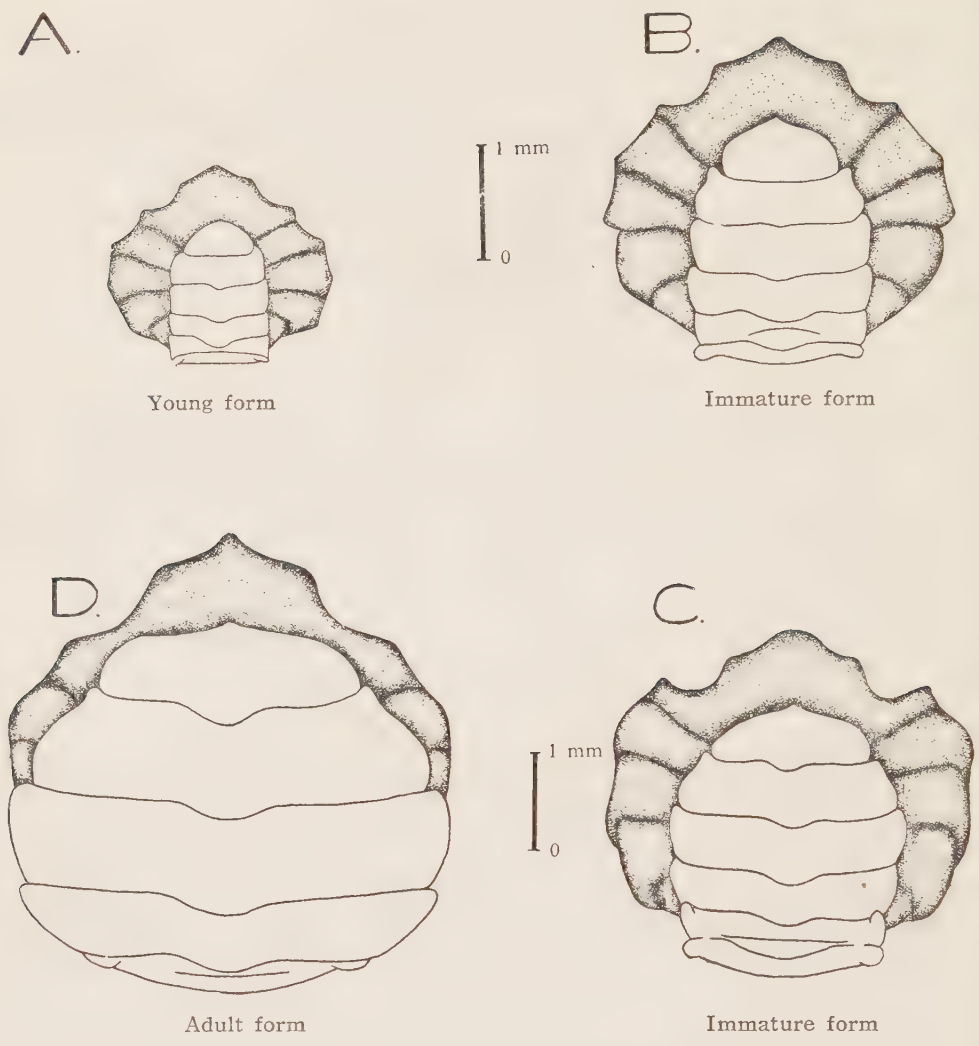
雄についてはその未熟，成熟の区別を省いた　すなわち，雄は外観からの判断ができないのと，大型のものは市価がいちぢるしく高価で入手できず，そのほとんどを魚市場で一時借用した関係上，剖検できなかつたためである。

結果と考察

雌： 雌の稚ガニが未熟ガニを経て，さらに成熟ガニに達する過程について，その腹部外形を概観すると，第2図に示したように腹部は，稚ガニでは巾が狭く，胸部腹甲がいちぢるしく張出しているが，[illegible]に伴い第1～5腹節が左右に伸び，成体（甲巾 52mm 以上）に達すると，それらは腹部腹甲のほとんどを覆つてしまうほど増大する。つまり，甲巾の成長に伴い腹部の形態が顕著な変化をすることが観察される。

稚仔の未熟期（第2図—A，B，C）における第1～5腹節は胸部腹甲に密着しているが，成熟（第2図—D）するとそれらは巾の増大とともに，内側に幾分か彎曲し，抱卵するので胸部腹甲から離れる。第6腹節はほぼ中央部を横走する稜線から屈折し，未熟の間はほぼ直角に折れているが，成熟したものではその度合がゆるくなつている。第7腹節は腹部の基部で，その先端は頭胸甲後縁の内側で胸上部に相接しているが，形態変化は相対的な長さを幾分増すというだけに限られる。

第6腹節の巾と甲巾との関係は第3図—Aの通りである。すなわち，第6腹節の巾は甲巾と1次の回帰関係にあり，脱皮による成長の度合が，他の腹節の場合と異り，飛躍的に増大することは見られない。つまり，甲巾との回帰係数は一定であるので，これを後述する腹部指数算出の基礎に使用した。

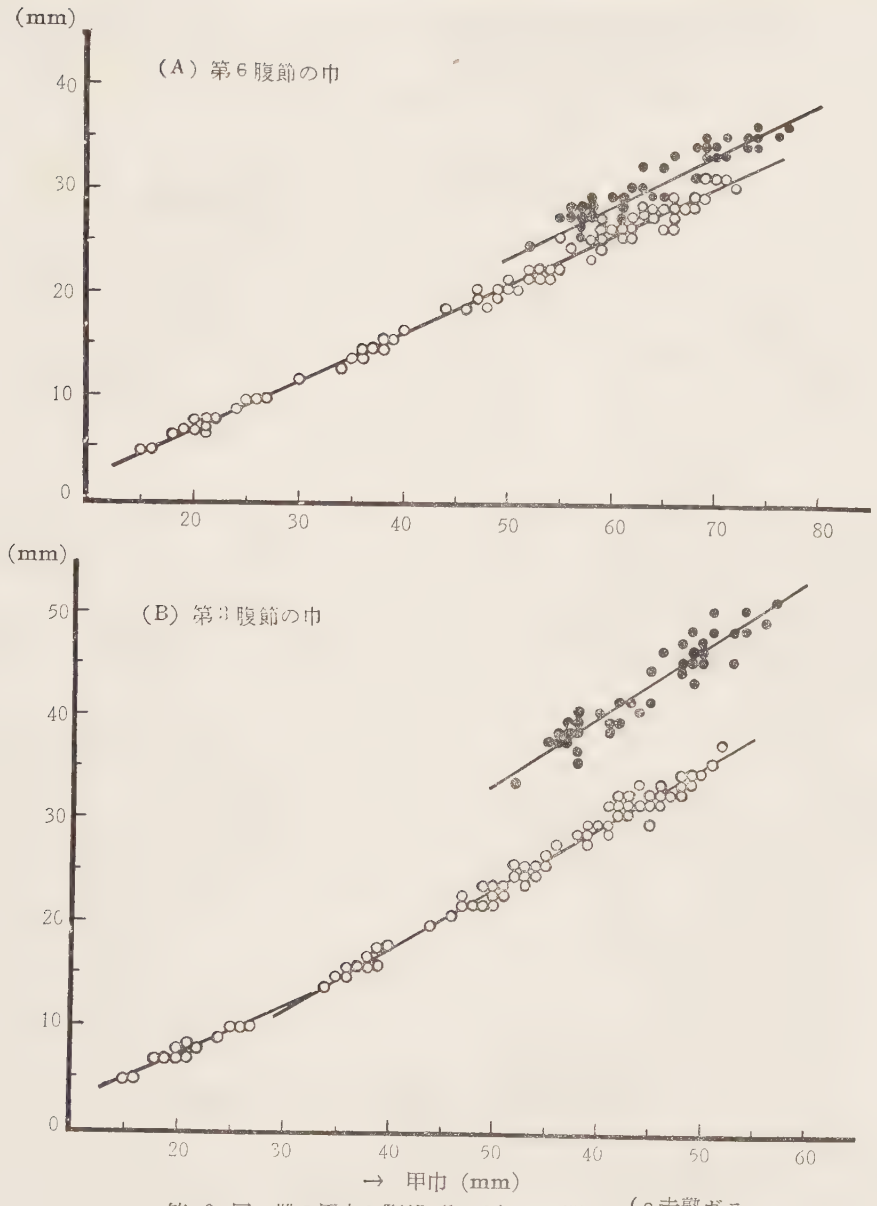


第 2 図　雌の成長過程における腹部形態

A　甲巾　145mm……幼 生 形
B　　32mm
C　　49mm　……未成熟形
D　　67mm……成 熟 形

第 1 ～ 5 腹節の巾も成長に伴いいちぢるしく増大していくが，この中でもいちぢるしい増大を示すのは，第 3 腹節である．第 3 腹節の巾と甲巾との関係をみると第 3 図－B のようになる。第 3 腹節の巾は図で明らかなように，前述した第 6 腹節が甲巾に対して一定な成長をするものとは異り，その過程中，甲巾 30mm 前後と，未熟から成熟に達したときに，相対成長において それぞれ 変曲点が存在する。すなわち，甲巾 30mm 前後から甲巾に対してやや速かな伸びを示し（第 1 変曲点），さらに未熟と成熟との間に，相対成長の位置にいちぢるしい差異（甲巾 65mm で約 13mm）があるだけでなく，幾分の増大を示していることが観察される（第 2 変曲点）。

第 3 腹節の巾の成長過程に見られた 2 変曲点から，第 6 及び第 3 腹節の巾の段階別相対成長は第 1 表で示



第 3 図　雌の甲巾と腹部 (l_1, l_2) との関係　{ ○未熟ガニ ●成熟ガニ

第 1 表　雌の甲巾に対する腹節巾の成長段階別　回帰直線

段階 / 測定部位	未熟 甲巾30mm以下	未熟 甲巾31mm以上	成熟
第6腹節の巾	0.457L − 1.846	0.487L − 3.008	0.476L + 1.237
第3腹節の巾	0.457L − 1.846	0.596L − 6.170	0.665L + 0.553
個体数	23	100	50

される。回帰直線の"傾斜の差"は第3腹節では3段階とも有意（危険率5%，以下同じ）であるが，第6腹節では認められない。したがつて，第6腹節の未熟期の相対成長は 0.476L－2.368 で示される。さらに伊藤（'53）の式によつて回帰直線の"位置の差"の検定をおこなつた結果（第2表—A，B，C参照），第

第2表　雌の甲巾に対する腹節巾の回帰直線の"位置の差"の検定

(A)　未熟ガニ（甲巾 31mm 以上）と成熟ガニとの第6腹節の巾

要因	変動	自由度	不偏分散
Parallel line	103.918	147	0.707
Positional difference	308.007	1	308.007
Single line	411.925	148	F_0=435.715
			F(5%)=3.910

(B)　未熟ガニ（甲巾 31mm 以上）と成熟ガニとの第3腹節の巾

要因	変動	自由度	不偏分散
Parallel line	504.154	147	3.430
Positional difference	3042.949	1	3042.949
Single line	3547.103	148	F_0=887.261
			F(5%)=3.910

(C)　未熟ガニの甲巾 30mm 以下と 31mm 以上との第6腹節の巾

要因	変動	自由度	不偏分散
Parallel line	107.880	120	0.899
Positional difference	2.925	1	2.925
Single line	110.805	121	F_0=3.253
			F(5%)=3.923

第3表　雌の甲巾に対する各脚長節長・段階別の回帰直線

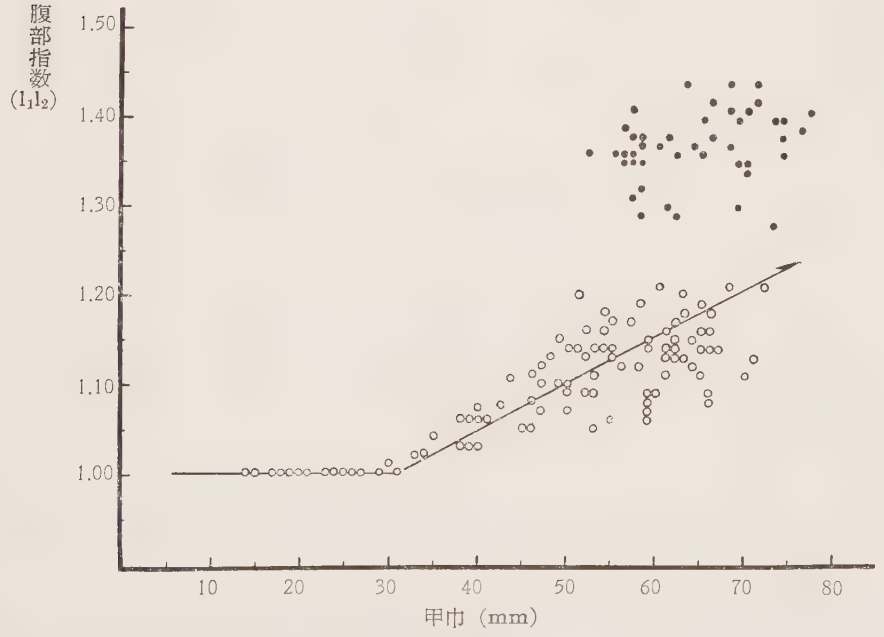
脚名＼段階	(a) 甲巾30mm以内	(b) 甲巾31mm以上の未熟	(c) 成熟	(b＋c)
鉗脚	(17) 0.336L＋1.370	(30) 0.341L＋0.820	(97) 0.287L＋3.699	(127) 0.306L＋2.378
第1歩脚	(13) 0.907L＋0.302	(28) 0.691L＋6.579	(78) 0.533L＋16.120	(106) 0.624L＋9.753
第2歩脚	(15) 1.057L－0.748	(28) 0.751L＋7.483	(73) 0.605L＋15.138	(101) 0.697L＋9.059
第3歩脚	(15) 0.943L＋0.677	(27) 0.643L＋9.468	(71) 0.532L＋15.613	(98) 0.579L＋12.325
第4歩脚	(14) 0.642L＋1.515	(26) 0.421L＋6.991	(78) 0.334L＋11.781	(104) 0.371L＋9.200

（ ）内数字は個体数を示す

第4表　雌の甲巾に対する各脚長節長・段階別の回帰直線の“傾斜の差”の検定

段階		(a) 甲巾30mm以下	(b) 甲巾31mm以上の未熟	(c) 成熟	(b + c)
鉗脚	(a)	—	(44) 0.862<4.063	(114) 2.707<3.929	(141) 7.500>3.907
	(b)		—	(124) 3.913<3.921	—
第1歩脚	(a)	—	(38) 6.239>4.100	(88) 4.110>3.944	(119) 10.885>3.925
	(b)		—	(103) 2.034<3.938	—
第2歩脚	(a)	—	(40) 4.390>4.080	(85) 4.229>3.950	(116) 13.333>3.927
	(b)		—	(98) 1.104<3.924	—
第3歩脚	(a)	—	(39) 6.726>4.009	(83) 5.648>3.934	(113) 15.826>3.930
	(b)		—	(95) 1.000<3.930	—
第4歩脚	(a)	—	(37) 6.299>4.105	(89) 3.975>3.942	(118) 17.063>3.926
	(b)		—	(101) 1.431<3.939	—

表中，不等記号の左側数字は F_0，同右側は $F(5\%)$ の値を示す。
また，n^2 = （ ）内の数字，n^1 はすべて1である。



第4図　甲巾と腹部指数 (l_2, l_1) との関係
○……未熟ガニ
●……成熟ガニ

3腹節の第1変曲点では“位置の差”はないこと，未熟と成熟の間では第3，第6腹節とも有意差があるといえる。

甲巾と腹部指数（$l_2/l_1 = k$）＊との関係（第4図参照）を見ると，前述した2つの変曲点はさらに明らかになる。すなわち，甲巾 30mm 以下の稚ガニでは l_1 と l_2 が等しいため，k は 1.00 で示されるが，甲巾 30mm 以上の未熟ガニでは l_1 に比して l_2 の伸びが大きくなるので，K は 1.01 から 1.21 の間に見られるようになる。成熟したものではさらに l_2 が大きくなつて，k は 1.28 から 1.44 を示している。

甲巾に対する腹部指数の変化を見ると，とくに甲巾 30mm 以上の未熟ガニでは，成長に伴い指数が増加し，その変異が大きいことがわかる。成熟ガニでは指数の増加はほとんど認められない。このことは，前者が初成熟に達する個体の大きさに変異が大きく，後者では雌が成熟直前の脱皮以後は成長をしないからであろうと考えられる。

以上を総括すると，雌の腹部形態は，腹部指数 1.00 を示す甲巾約 30mm 以下のもの，1.01 から 1.21 の間において甲巾の増大とともに腹部指数を増大していく甲巾約 30mm 以上の未熟なもの及び 1.28 から 1.44 の成熟したものの3期に区分して考えることができると思う。

① 幼生型 Young form　（第2図—A）　（甲巾約 30mm 以下）
② 未熟型 Immature form　（第2図—B，C）（甲巾約 30mm 以上の未熟）
③ 成熟型 Adult form　（第2図—D）　（甲巾 52mm 以上）

筆者の観察では，未熟ガニの生殖腺の存在を肉眼で識別することができたのは，甲巾 33～40mm 以上のものであつて，甲巾 30mm 以下ではまつたく観察できなかつた。したがつて，甲巾 30mm 前後において腹部形態に変化を生ずるのも，こうした生理的変化と対応している形態変化のあらわれであるかもしれない。

甲巾に対する第3及び第6腹節の巾の相対成長は，すでに第3図—A，B，第2表—A，Bで未熟と成熟との間に“位置の差”が有意であり，さらにその間に甲巾 65mm において第3腹節で約 13mm，第6腹節で約 3mm の差があることを示しておいたが，このことは，未熟から成熟に達する最後の脱皮には，それまでの脱皮成長に見られた甲巾の増大はほとんどなく，腹部の増大だけおこなわれる，つまり，成熟直前の未熟ガニはその大きさ（甲巾）のままで脱皮し，その結果腹部の形態変化（未熟型→成熟型）だけおこなわれるらしいということが示されるのである。

雄：まず腹部の外形を観察すると（第5図参照），第1～5腹節のうち第5腹節の巾を最大とし，順次上方の腹節ほどその巾が狭くなつている。第6腹節は第5腹節よりその巾が幾分小さく，そのほぼ中央を横走する稜線で内側に屈折するが，屈折の度合は未熟な間はほぼ直角に，成長するに伴い，ゆるくなる傾向があるが，第1～5腹節は胸部腹甲に密着していて，雌のように成熟しても離れるようなことは見られない。

小型なものと大型なもの（甲巾の大小をいう一材料の項参照）とを比較してみると，第1～5腹節は後述するように，それらの巾の伸びがほぼ一定であるため，差異は見られないが，甲巾 40～50mm から，第1腹節を除いた各腹節の中央部に稜線状の隆起を生じ，成長に伴い隆起の度合を増すことが観察される。

次に，第6腹節の巾は甲巾に対して1次の回帰関係にあることは雌と同様である。第3腹節もまた同様であるので，回帰関係は

第3腹節 $(l_2) = 0.274\,\mathrm{L} + 1.590$
第6腹節 $(l_1) = 0.295\,\mathrm{L} + 2.297$

が得られる。つまり，雄では雌の場合と異つて，ある特定の腹節が特定な成長段階（脱皮）で，顕著な伸びを示すというような現象は見られない。

(2) 脚長節の相対成長

材料　供試材料は総計 375 尾，雌 132 尾，雄 243 尾であり，雌は鳥取県賀露沖（農林 58 海区，水深約 220～240m）から，1954 年3月に1回採集したが，雄は漁期外のため材料の蒐集が困難であつた。したがつて，雄は 1954 年1月から5月にわたり 12 回にわたり，漁獲位置も前記賀露附近（農林 58，65，72，78，

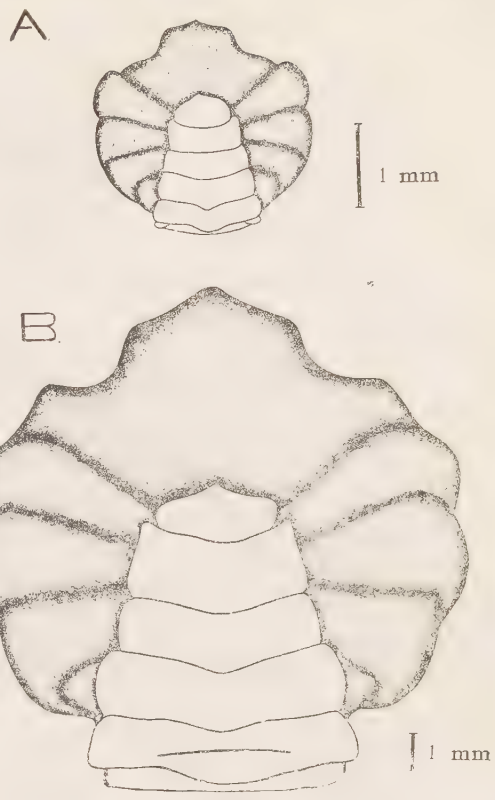
＊ 腹部の形態変化をあらわすのに腹部指数として $\left(\frac{\text{第3腹節の巾}}{\text{第6腹節の巾}}\right)$ を用いた。

85海区）並びに隠岐島西方～見島近海（農林99, 107, 127, 201, 245, 257海区）などの広範な水域から採集した。なお，雄の漁獲水深は200～250mであつた。

結果と考察

雌：第6図は雌の甲巾と各脚長節長との関係を示したものである。図によれば鉗脚以外の他の4脚，すなわち第1，第2，第3及び第4歩脚各長節の甲巾に対する相対成長は，いずれも甲巾30mm前後に1つの変曲点をもつて成熟まで達していることがわかる。

前項の腹部の場合でも，甲巾約30mmの点で相対成長に差が見られたが，脚長節の場合にもこの点（甲巾30mm前後）で明らかに有意差が現われている。しかし，腹部で見られたような未熟から成熟に移行するときの変化は脚長節ではまつたく見られなかつた（第3表，第4表参照）。しかも，この脚長節の相対成長の変化は，腹節のそれが甲巾に対して増大傾向をもつているのに，脚長節では甲巾約30mm以上，成熟に達するまで同一の伸びである。



第5図　雄の成長過程における腹部形態
（A　甲巾　28mm）
（B　甲巾　100mm）

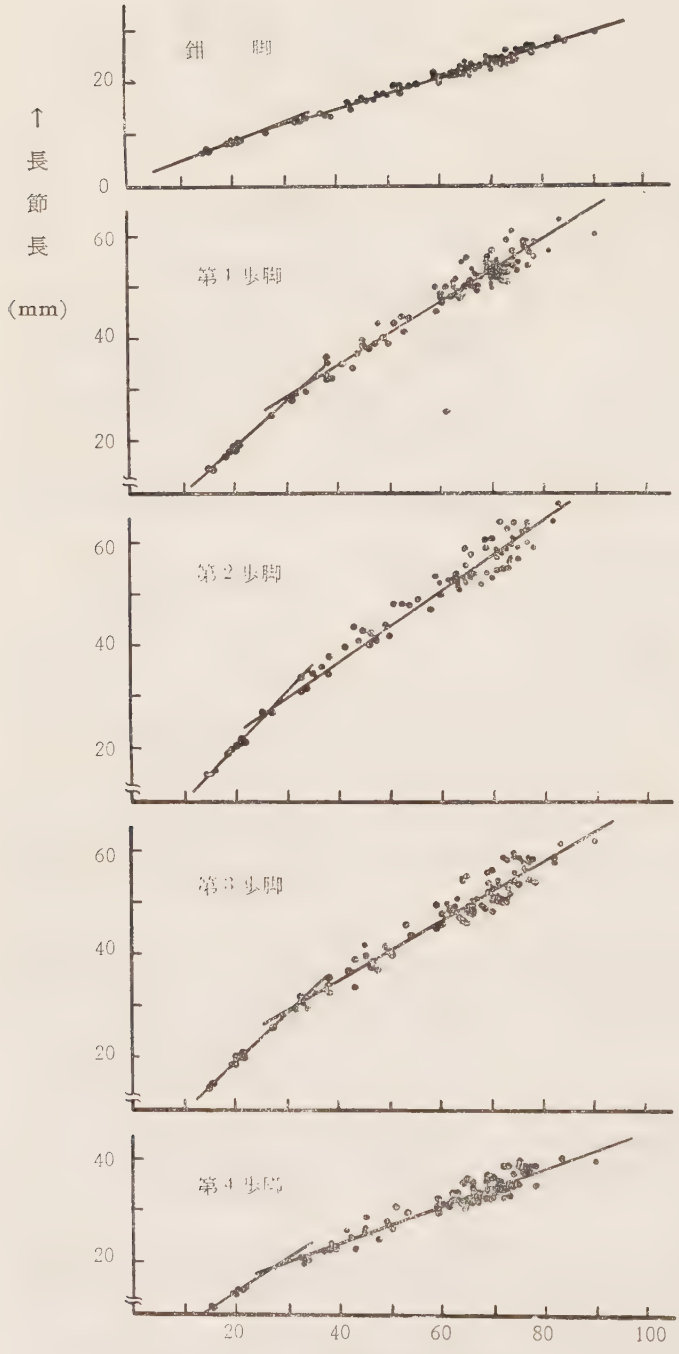
以上をまとめてみると，雌の脚長節の相対成長にも甲巾30mm前後に変曲点があり，長節の伸びは鉗脚を除いて甲巾に対し低下する。さらに成熟直前に達した大きさのまま脱皮するといえる。したがつて，脚長節がそのままということは，前項の腹部が初成熟の際の脱皮に，甲巾の増大を伴わないという現象との関連を示すものと思われる。

雄：第7図に雄の甲巾と各脚長節長との関係を示したが，ここで特記しなくてはならないことは，雌の場合とは反対に甲巾70mm前後から長節が甲巾に対して顕著な伸長を示していて，緒言で記した松浦の結果とはまつたく異ること，さらに注目すべき事実として，鉗脚の場合にだけ，長節長が甲巾に対していちぢるしく増大した群と，そうでない群の2つの存在が挙げられる。いま，前者をA群，後者をB群とすると，A，B2群の現われ方は，両群とも甲巾70mm前後からであるが，その分布はB群が甲巾110mm以下であるのに対し，A群は甲巾150mm位まで広く分布している。

既述のように雌の場合ではその成長過程中，甲巾30mm前後に変曲点があり，腹部の形態変化がおこなわれるが，雄では甲巾70mm前後まで各脚ともそれぞれの関係式をもつて同一回帰で成長しているといえよう。

雄の未熟，成熟をその外形から区別できないことは前項で述べたように，筆者はまだこの点についての調査がないが吉田（'50）が報告した雄の生物学的最小形である甲巾66mmをやや大き目にとり，甲巾70mmを成熟の一応の目安として考察を進めたい。

脚長節を甲巾70mm以下と71mm以上とに分け，甲巾との回帰関係を示すと第5表のような結果となる。前述したように鉗脚だけに明らかに2群が存在するので第5表の鉗脚の回帰関係をA，Bの2群に特記した。これより段階別の差の検定をおこなつてみると，甲巾71mm以上のものにやや係数の増加がどの脚



第6図　雌の甲巾と各脚長節長との関係

からも認められるが，有意差があつたのは鉗脚だけである。

鉗脚の長節の長さが，甲巾70mm 前後で，それまでの相対成長と違い，その結果増大傾向を示すだけでなく，甲巾に対しいちぢるしく増大した群（A群）が見られることは，前述した通りであるが，さらに他の4脚について検討してみた結果（第6表A—E），鉗脚はもちろん他の4脚とも同様に，“位置の差”は有意であるといえる。すなわち，甲巾 71mm 以上ではA群はB群よりも甲巾に対し長節の長さが，

鉗　脚……7 ～ mm
第1歩脚……7 ～ 8 mm
第2歩脚……7 ～ 9 mm
第3歩脚……5 ～ 6 mm
第4歩脚……4 mm前後

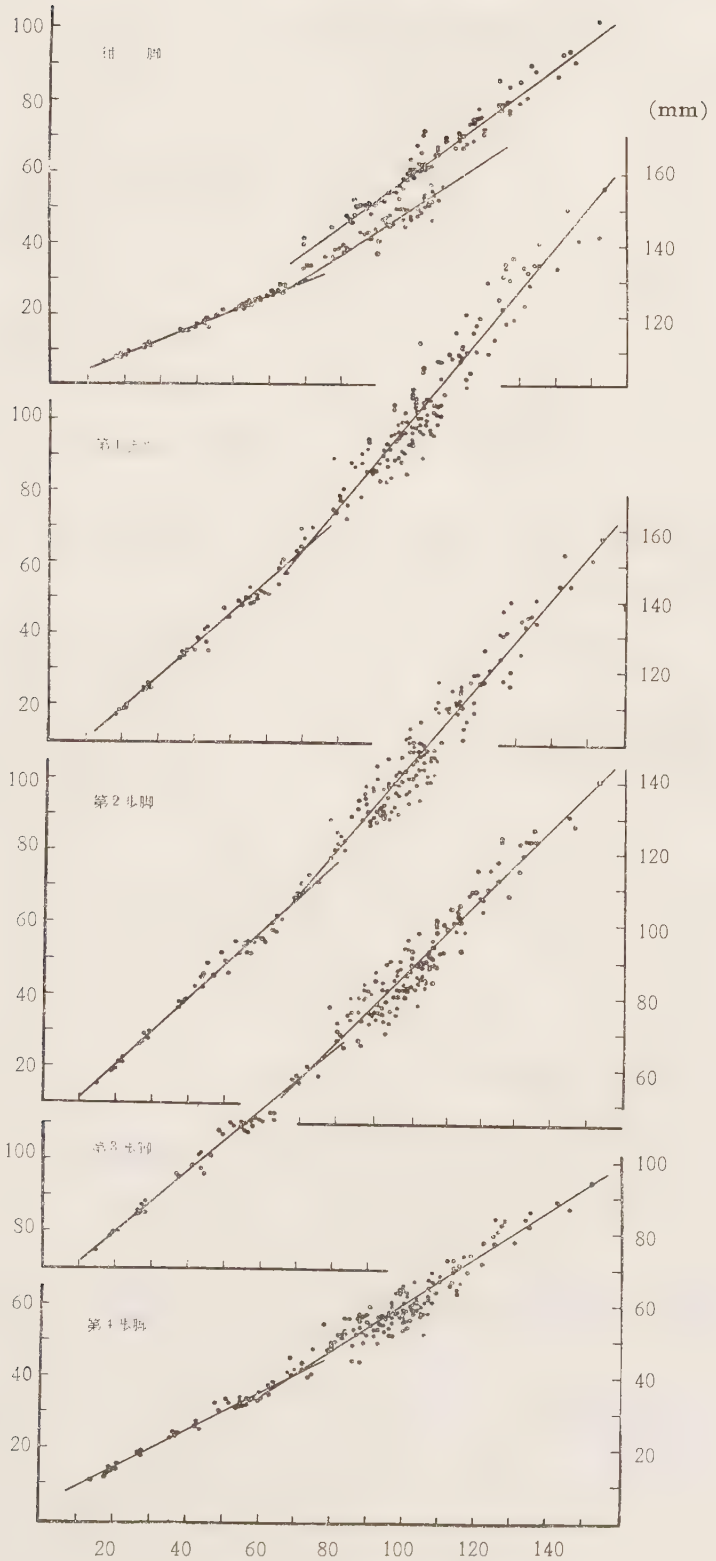
長いといえる。この理由についてはいまのところ充分納得のいく説明ができないが，既述の雌の腹部形態の変化と同様に，性的生態と形態との関連を示す一つの現象であろうと思つている

Ⅳ 摘　要

日本海西南海区産のズワイガニについて，甲巾に対する腹部及び脚長節の相対成長を調査し，次の結果を得た。

1) 雌の腹部形態の変化から，つぎの3つの時期に分けられる。すなわち，

① 幼生型（Young form）
② 未熟型（Immature form）
③ 成熟型（Adult form）



第7図　雄の甲巾と各脚長節長との関係

第5表　雄の甲巾に対する各脚長節長の段階別の回帰直線

脚名＼段階	甲巾 70mm 以下	甲巾 71mm 以上
鉗脚	$0.420L - 0.270$ (61)	(A)$0.742L - 14.555$ (102) (B)$0.680L - 17.282$ (73)
第1歩脚	$0.901L + 0.923$ (57)	$1.224L - 21.490$ (162)
第2歩脚	$0.926L + 2.822$ (57)	$1.179L - 13.903$ (163)
第3歩脚	$0.868L + 2.464$ (53)	$0.997L - 6.476$ (156)
第4歩脚	$0.527L + 4.102$ (57)	$0.646L - 4.573$ (157)

(A), (B) はそれぞれA群，B群であることを示す。（ ）内数字は個体数

第6表　雄（甲巾71mm以上）の甲巾に対するA，B 2群の回帰直線“位置の差”の検定

（A）鉗脚

要因	変動	自由度	不偏分散
Parallel line	1374.979	172	7.994
Positional difference	2809.002	1	2809.002
Single line	4183.982	173	$F_0 = 351.384$
			$F(5\%) = 3.911$

（B）第1歩脚

要因	変動	自由度	不偏分散
Parallel line	3732.447	147	25.391
Positional difference	1693.320	1	1693.320
Single line	5425.767	148	$F_0 = 66.690$
			$F(5\%) = 3.911$

（C）第2歩脚

要因	変動	自由度	不偏分散
Parallel line	4647.588	145	32.052
Positional difference	931.943	1	931.943
Single line	5579.531	146	$F_0 = 29.076$
			$F(5\%) = 3.912$

(D) 第 3 歩 脚

要 因	変 動	自由度	不偏分散
Parallel line	3282.148	139	23.613
Positional difference	691.927	1	691.927
Single line	3974.075	140	$F_0=29.303$
			$F(5\%)=3.914$

(E) 第 4 歩 脚

要 因	変 動	自由度	不偏分散
Parallel line	1407.032	139	10.123
Positional difference	716.500	1	716.500
Single line	2123.532	140	$F_0=70.783$
			$F(5\%)=3.914$

腹部の形態変化は甲巾 30mm 前後に 1 回，初成熟（甲巾 56mm 以上）の際に 1 回おこなわれるが，初成熟に達した未熟ガニは，そのままの大きさで脱皮するようである。

2）雄の腹部形態は変化しない。

3）脚長節長は甲巾に対して

雌では，甲巾 30mm 前後

雄では，甲巾 70mm 前後

にそれぞれ異つた相対成長をし，前者では縮小傾向に，後者では増大傾向に変化する。

4）甲巾に対する鉗脚の相対成長から，甲巾 70mm 以上の雄ガニに，2 つの異つた群が存在することを認めた。

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ヤリイカ *Lolgo Bleekeri* KEFERSTEIN の交接行動

浜 部 基 次・清 水 虎 雄

The copulation behavior of Yariika, *Loligo Bleekeri* K.

By

Motoji HAMABE and Torao SHIMIZU

KISHITANI ('32) reported anatomically and histologically, that *Loligo edulis* contains the symbiotic luminous bacteria in the mantle cavity as the open-type of luminous organ but he never observed any luminosity. The author, however, saw the luminescence of *L. breekeri* in living condition througth the experiment.

The copulation behavior of Yariika was observed in Urago-Bay, Oki Island, during the period between March 14th to 28th 1955.

Yariika is one of the commonest and widely distributed cuttlefish in Japan, and approaches to the beach in the bay for copulation and spawning in early spring-time. The copulation is performed on the sea surface at about sun-set time. Copulation postures and roles of each arm are shown in Figs. 1. A–F, that is the male turns over his first paired arms, and sticks item to female's abdomen, erecting his second pair vertically, embraces female's head with them and getting entangling his third pair with female's same pair, turns his fourth left arm (hectocotylus) over, inserts into the femele's mantle, ejaculating sperms. Immediately after copulation, the female sinks down to the sea-bottom, turning white and glimmers and without changing her position, she lays stender bunches of eggs before next morning.

In shallow crawl, a female was seen to be occupied exclusively by a strong male, and a struggle among males was also observed.

小久保 ('38) によれば，スルメイカの雌雄は丁度我々が指を組むように脚を互に纏絡させて交接し，ヤリイカの交接方法もこのスルメイカの方法とまつたく同様であるという。しかし，諫早・佐久間 ('34) によれば，ヤリイカの方法はスルメイカと同様に相互に脚部を纏絡することもあるが，主として雌は脚を使用せず，雄が雌の頸部に纏絡することが多いという。諫早・川上 ('34) はこれと別にスルメイカの交接の基本型を図示して詳説しているが，その原図は雌雄の区別が不明であり，脚の纏絡が複雑で，脚の位置とそれに関連した役割を知るのに不便であつた。筆者らは 1955 年 3 月生簀網内でのヤリイカの交接，及び自然環境でのヤリイカの交接をしばしば観察し，雌雄の脚は左右相称的に相互にかなり整然と纏絡しており，その役割も特徴的に分化しておつて，決して雑然と不規則に纏絡しているのではなかつたので，その状態を報告する。

観　　察

場所及び時刻　浦那湾奥由良浜地先は，波浪静温，岸深でその水際は褐藻（モク類）が濃密に繁茂し，この周辺部に例年3，4月ごろ日没薄暮の時刻にヤリイカ（方言チヨギ，テナシ）が接近浮上し，水音波紋を立てて，交接浮上することが知られている．筆者らは現場にて擬餌鉤で掛釣りし，雄には標識として白ペンキを塗付した延縄鉤を内鰭に刺し止め，直径 2m，深さ 3m の丸型網生簀（網目 10cm 間9節）に雌雄各5尾を収容し，午前9時，12時，日没時前後に錨留位置に船を停め，生簀全体を水面近くへ引揚げ，交接時には水面への浮上障害とならないよう生簀をさらに引揚げ調節して観察した。餌料は全然補給しなかつた。

表 I　環　境　条　件

日時	3月14日 17.00～19.30	15日 16.00～21.00	16日 10.00～12.00 17.00～20.30	17日 10.00～12.00 17.00～21.30	18日	19日	20日	21日 17.00～20.00	22日	23日	24日 17.00～20.00
日没時刻（大阪標）	18.05	18.06	18.07	18.07	18.07	18.08	18.10	18.11			18 13
風向	SW	S	W	SE—W	W	W	S	S			W
風力	Calm	Calm	2	強風注意報 7～8	強風 8	強風 6	2	Calm			Calm
雲量	0	0	2	10	10	5	10	0			0
天気	○	○	○	◎ ●	●	●	◎	○			○
表面水温	13.0°C	13.6°C	欠	欠				13.2°C			13.1°C
漁場水深	5m	5	5	5				5			5
試験観察	試釣 20尾成功	4時出漁 10尾を釣獲，船上にて雌雄に区別し，標識し，生簀に放つ，網生簀は現場に垂下	午前の状態 網底にかたまつている，鎮静，相互に無関係 午後 太陽が山に懸る頃より俄然優乱交接2回	午前 沈下鎮静 午後 日没 太陽が山に懸ると俄然優乱交接たし 低気圧接近好漁うら尾動物交換に尾	低気圧中止	低気圧中止	低気圧中止	疎暮 9尾死 1尾健在 釣獲 0 補充不能			釣獲 0 補充不能

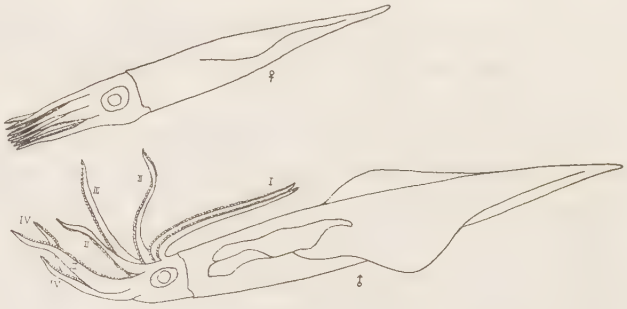
当時の漁場の状態　1954，1955年2，3月の間に筆者自身釣獲したもの43尾の性比は♀22：♂21。外套背長♀ 181cm，♂ 219cmであり，当時の漁況は日没を中心としてその以前に多獲され，日没後は集魚灯を用いてもあまり効果的でなかつた．低気圧の襲来前に豊漁し，大雨後には皆無となるなど，その性状はイカ類一般と大差ないもののようである．また，その群成状態は小数ずつの断続した釣獲状態から推定していくつかの小群が移動，離散していることを示し，漁獲物を時間区分によつて調査したが，雌雄いずれか一方のみであるような特殊なものはなかつた．

交接の行動　1955年3月16日17時から20時30分の間，ヤリイカの交接（同一姿態）を2回観察した。生簀内での行動は，10時以後夕刻までは，生簀底から10～20cm 位上の下層に分散し，ほとんど運動せず，

相互に間隔を保ち，接触や追つかけあいとか攪乱をせず，雌雄混合して鎮静であり，各種の刺戟を与えても無反応に近かつた。しかし，夕刻の日没時ごろから，群全体が上層の浮上し，各自右往左往の混乱した運動を起し，その運動は生簀に直射光が投射しなくなつてから激烈を極め，事物の識別困難となる頃にはかなり沈静した。交接は前述の浮上擾乱の間に行われた。交接体位，各番の脚の役割，雌雄の行動の大要は図Ⅰの A～Fに示し，これに若干の説明を加えると，

（A）巨大の優位雄のみが左右第1腕を頭上に反転し，体色白変，臓器附属の発光器で発光しつつ，游泳する。岸谷はこのイカの発光器について解剖，組織学的に研究し，開孔式である旨発表しているが，発光器内に一種の共棲菌の存在を確認し，これが純粋判定を行つているが，生時における発光を観察していなかつた。だから，果してこの器管が発光器としての役割を果しているかどうかという点が残されていたので，この点について著者は視察した。ここで注目されるのはイカに限らず他の2，3の Cephalopoda では第1腕の挙動が何等かの情緒的興奮を指標するようにみえることである。

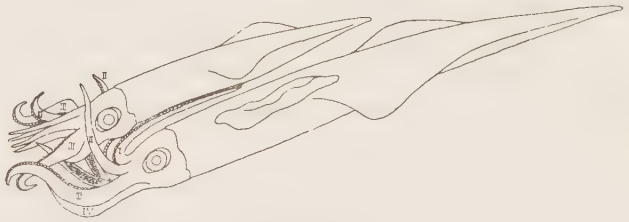
第1図　A　　I～IV　Arm number



第1図　B

（B）雌に接近し，接触すると，雌も感応して白変発光する。

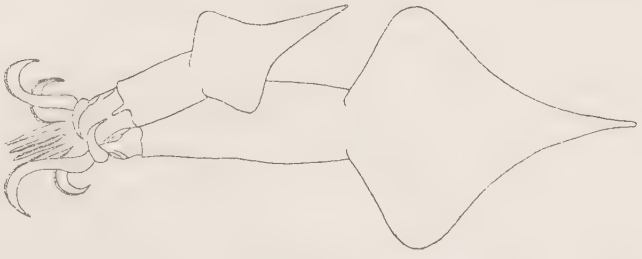
（C）雄は左右第1腕を反転して雌の腹部に吸着し，活溌に鰭をあうる。捕捉された雌は直ちに白変発光をやめ，普通の体色にかえり，ほとんど活動せず，腕を自然な形に伸長し，次いで第3腕を体軸の左右に鋏型にそりかえらせる



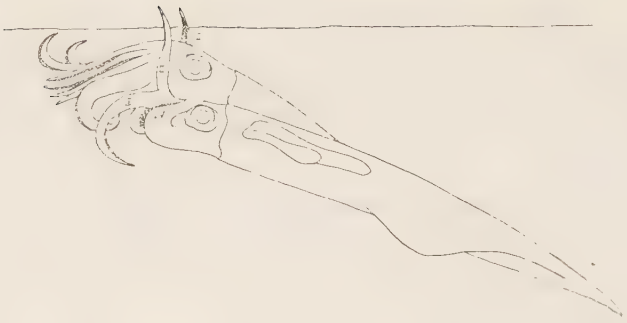
第1図　C

第1図　D

（D）雄は第1腕で雌に吸着し，第2腕で雌の頭部眼の附近を差しあげるように挟持し，第3腕で，雌の第3腕と鋏型の交叉をし，以上の3点で雌の保持を確実にする。第4左腕は反転して自己の頭部側面にそつて伸長し雌の外套内に挿入する　こ



第1図　E



第1図　F

のころ雄の鰭の飜振回数が多く，依然白変発光のままで次第に緩慢な旋廻運動を起し，水面に水平位におる雌に斜下方から約30度の傾角で徐々に雌を押し上げ，頭脚部を表面へ向けて浮上してくる。雌は終始不活潑で受動的である。

（E）Dの瞬観図。

（F）交接雌雄は，中層から漸次表層に浮出し，雄は左右に直立した第2腕で交互にリズミカルに雌の頭側面を軽打する。雌の頭部はこのころ遂に水面上に露出しており，軽やかな雄第2腕の運動による波紋と雌頭部の出没の波紋を水面に起しつつ彷徨する。このさい雌はほとんど鰭も動かさない。

Hectocotylized Arm である雄第4左腕は反転してからの延長経路は識別困難であつたので，交接終了後雌の外套より離脱し，収縮していく経路を逆に辿つた。第4左腕は反転と同時に，その基部が美麗なルビー輝色を呈し，迅速に運動し，密接に吸着している一連の吸盤環の色調に由来すると考えられた。

交接時間は1回約5分位と認められたが，正確に計測していない。交接行動間網地を調節し，手指を出し，顔を近づけ種々観察したが，彼等は何等の影響も受けなかつた。交接終了は雄の第4左腕が雌外套から離脱し，他の腕の交叉，吸着もほとんど同時に解脱され，雄の白変発光がこの時にいたつてやんだ。

交接後雄は盛んに他の雄を捕捉攻撃し，雌は直ちに簀底へ沈下し，沈下と同時に単独で白変発光を開始し，網地に沈着したが，翌朝までの間にそこに長紡錘形の卵嚢を産出していた。

生簀内のヤリイカの行動　交接行動を観察中にかなり特徴的と考えられる次の行動が認められた

(1) 雌は全体として非活動的で，生簀の中層に集団し，雌のみの集団を形成する。この際，雌同志の間には雄同志に見られるような角逐はない。

(2) 雄は活潑に運動し，雄同志盛んに角逐し，嘴をむき出し頭脚部を噛み合い，腕部の縺絡を見せる。この雄同志の闘争は，とくに体躯巨大な1尾によつて徹底的に行われ，他の雄は次第に生簀の縁辺部へ圧追され，雌の集団を中心として隔離されるようであつた。雄はいずれも雌を攻撃しない。これは群中の最大最強雄による雌の独占とも考えられる。

(3) 雄同志の闘争は，垂直位，斜交位で互に接近し，大型な方が大体に他の者の進路の腕を展開し突進する。小型の方は最初腕を多少展開しかけるが，進路を変更し逃走する。このさい攻撃者で勝者となるものは攻撃開相手が逃避するまで白変発光しているが，敗者は直ちに発光をやめ，腕を自然な状態に伸長し，勝者に頭脚部を2～3度咬まれるあいだ，抵抗らしい抵抗をしない。交接したのは巨大雄1尾であつたから他の雄はその機会が得られなかつたようである。以上(1)，(2)，(3)の観察から諫早・川上の報告した交接図のうちⅡ，Ⅲについてはかなり疑問を抱いている。

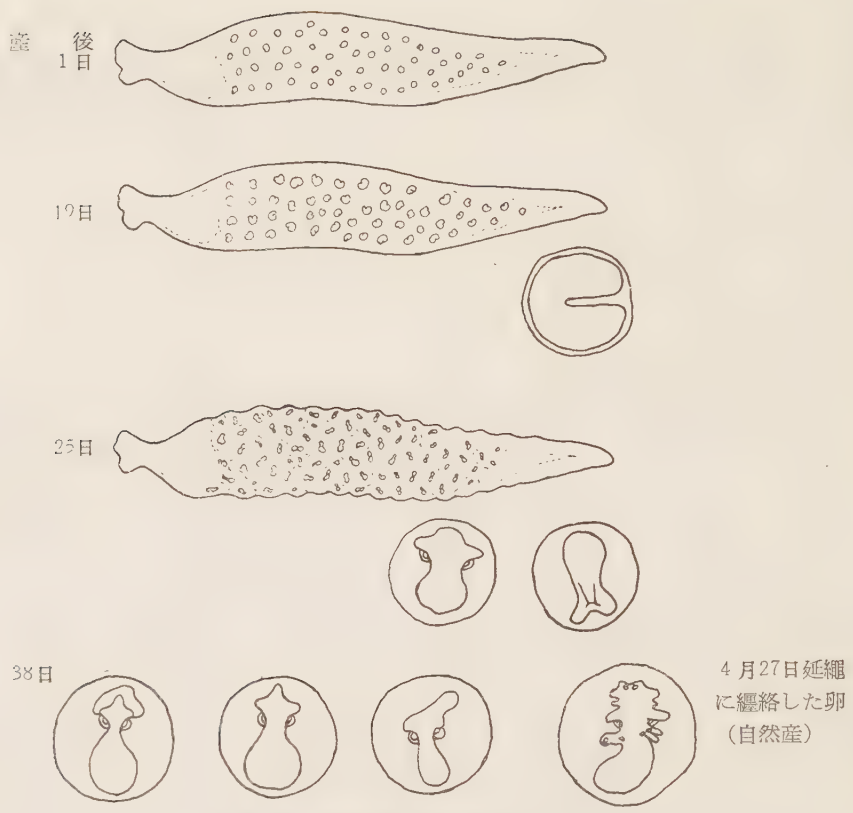
卵嚢の変化　交接観察中，3月17日に産出された卵嚢2個を3月26日実験室内のガラス水槽(直径30cm 深 13cm) に移し，換水することなく，室内常温の下において発生状態を簡単に観察した。

その結果，ヤリイカ卵は環境の悪化に対して相当の抵抗力を持ち，長期（約40日）にわたつて発生を継続した。しかし，水温が上昇し 15～20°C 附近では卵嚢表面に無数の気泡が発生浮上し，卵は白濁化した。embryo の motion が見られたのは産卵後約38～39日後であつたが，以上のことは裸出した「スルメイカ」卵が，人工授精後2～3日で死滅することと著るしい対照を示している。

表Ⅱ　卵の経過日数と容器水温

★（ ）内は換水後の水温
★ 夜間は測温せず

月日	産後経過日数	観察時刻	室温（C°）	水槽温 A（°C）	海水温 B（°C）	A－B 差
3月 18日	1					
26	9	15.40	9.6	13.6		
27	10	10.00				
4月 6日		15.00				
	20	8.30	15.6			
		16.30				
7	21	10.00	20.4	17.8		
8	22	8.30	21.4	18.4 (15.4)	15.4	+3
9	23	9.00	22.1	18.6 (15.2)	15.2	+3.4
		13.00	23.4	19.5 (17.2)	17.2	+2.3
		18.00	21.7	19.8 (14.8)	14.8	+5
10	24	放置				
11	25	18.00	18.3	16.8 (15.1)	15.1	+1.7
12	26	9.00	21.5	17.8 (15.7)	15.7	+2.1
		12.00				
		13.30	22.8	19.1 (16.0)	16.0	+3.1
		17.00	21.9	18.2		
13	27	9.00	22.4	20.0 (15.4)	15.4	+4.6
		13.00	23.7	20.5 (15.7)	15.7	+4.8
		17.00	20.0	18.5 (15.2)	15.2	+3.3
14	28	8.30	14.0	13.2		
15	29	8.30	17.2	16.4		
		17.00	18.4	16.7		
16	30	9.30	17.7	17.2		
17	31	12.00	13.6	13.6		
18	32	9.00	10.0	10.0 (13.4)	13.4	−3.4
19	33	9.00	10.5	9.3 (13.0)	13.0	−3.7
22	36	12.00	16.3	14.6 (15.4)	15.4	−0.8
23	37	10.00	15.8	13.2 (14.7)	14.7	−1.5
		18.00	15.9	15.6	15.0	
24	38	12.00	17.3	15.3		
25	39	15.30	16.7	15.0		
26	40	16.00	17.7	15.9		
27	41	17.00	19.7	18.5		
28	42	8.00	17.4	15.7	15.8	−0.1
5月 2日	47	8.00	18.5	16.3 (16.1)	16.1	+0.2
4	49	9.00	18.4	17.2		
		14.00	19.0	17.5		
6	51	9.00	22.4	20.0	16.3	



第2図　経過日数と卵塊及卵

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1955年春季日本海北部海域における表層流について
—とくにマイワシ卵・稚仔の移流との関係—

笠　原　昭　吾

A Study on the Surface Flow in the Northern Japan Sea during the Spring, 1955, with Special Reference to its Bearing upon the Drift of Sardine Eggs and Larvae

By

Shôgo KASAHARA

Abstract

The present paper deals with the results of drift bottle experiments carried out by the writer when he was engaged in the sardine spawning research operation off Noto Peninsula in spring, 1955, with the aim of investigating the surface flow in the northern Japan Sea from the view-point of drift porblem of spawned sardine eggs and larvae.

(1) In April the littoral current along the nothern coast of Noto Peninsula was weak and appeared to flow quite near-shore into Toyoma Bay but in small quantities, whereas in May it became fairly strong, was stretched out far off-shore, and converged around the Promontory of Rokkosaki, flowing into Toyama Bay thrivingly.

(2) The NE directed off-shore current, after passing the Sado Straits, ran northwards, then was converged and pressed against the coast around the Promontory of Nyudozaki and the western entrance of the Tsugaru Channel.

(3) April through May, a large-scale horizontal vortex was recognized existing off Sado Island, making an anti-clockwise circulation prevailing in its vicinity. But it was no longer observed in June.

(4) In April the waters 5 to 10 miles off the coast of Noto Peninsula were estimated to have poured into the Tsugaru Channel to considerable measure, whilst those of 20 miles or so off-shore to have flowed into that channel by half, the other half going further north along the west coast of Hokkaido. In May, however, greater bulk of waters, irrespective of the position of origin, poured into the channel.

(5) Sardine eggs and consequent larvae originated from waters off Noto

Peninsula, the biggest sardine spawning ground in the Japan Sea, were considered mostly to have drifted through the Sado Straits in Aprli, a small portion going into Toyama Bay. Those spawned in May, however, may have been mostly driven into Toyama Bay.

(6) Both greater bulk of the sardine larvae carried through the Sado Straits and the eggs spawned in coastal waters north of Niigata Prefecture may have run into the Tsugaru Channel, there divided into three branch drifts, one into Mutsu Bay, another into Funka Bay and the third onto the Pacific coasts of northern Honshu.

ま え が き

能登近海がマイワシの産卵場として，日本海において重要な位置を占めていることは，最近のイワシ資源調査によつて確認されておるが，能登近海におけるその卵・稚仔分布については，その年の産卵場の形成位置と海流の流路によつてかなり相違があり，祿剛埼の沖を通つて流されるときもあり，あるいは祿剛埼の沿岸から能登内浦に多量に入る場合もあると指摘されている[1]。したがつて，マイワシの産卵と稚仔の成育期である4月～6月の能登近海，およびそれ以北の表層の流れを知ることが卵・稚仔の移行・分布，生残率等を考察する上に重要なことである。このような観点からイワシ資源調査の一環として，産卵調査と併行して海流瓶の投入による表層流の調査を実施した。その結果に基き，表層流ならびにマイワシの卵，稚仔の移行について若干の考察を加えたので，ここに報告し参考に供したい。

なお，この調査の機会を与えられ，かつ本稿に校閲を賜つた本研究所加藤源治資源部長，伊東技官，取纏めに際し終始御指導，御助言をいただいた同西村三郎技官に対し謝意を表する。調査に当つて協力していただいた第2旭丸船長綱市三郎氏ほか乗組員各位に厚く感謝する。

I　調査の概要並びに結果

使用海流瓶　海流瓶として使用したのはビール空瓶で，風圧面をできるだけ少くするために一定量の砂を入れ，瓶の胴部の大部分が水面下に没するよう調整した。蓋にはゴム栓を用い，その上をピッチで密封した。さらに瓶の発見を容易にするため瓶の外側を帯状に白塗した　抵抗板は用いなかつた。

投入点の位置　投入点は Fig. 1—(a) に掲げたように能登北西岸約 50mile の範囲内に分布しており，昭和30年度イワシ産卵調査定線観測の機会を利用して投入した。この他に新潟県水産試験場で実施した佐渡海峡，弾埼北西 45mile 線 Fig. 1—(b)における海流瓶投入の資料[2]も併せて使用した。

拾得率　昭和31年4，5，6月に投入し12月31日までに拾得報告のあつたもの（能登北西岸で5月に実施した投入点番号6～19のものは昭和31年7月20日までに報告のあつたものに限つた）についてみると，拾得率は4月実施のものでは，能登北西岸における投入のものについては31%，新潟県沖合のものについては24%であり，5月投入のものでは能登北西岸40%，新潟県沖合45%で，5月実施のものが高率を示している。6月投入のものは新潟県沖合のみであるが，21%となつている。

漂着状況　実施月別に各投入点ごとの漂着拾得の状況を表示すると Table 1, (a), (a′), (b), (b′), (c) のようになる。これから各地域への漂着には月によつて，あるいは投入点によつてかなり異つた傾向のあることがうかがわれる。そこで投入点を ① 能登北西岸の巨岸20浬以内の沿岸域，② それより沖合，③ 佐渡海峡，④ 佐渡外浦或に大別して地域別漂着の割合についてみると Table 2 に示したようになる。能登北西岸の沿岸域で4月投入したものでは比較的均等に各地域に漂着しているが，津軽海峡内へ流入漂着したものが31%でもつとも多い。沖合域投入のものでは富山湾までの近巨離地域への漂着は皆無であり，かつ

(a) Off NW coast of Noto Peninsula. Figures in parentheses refer to station number of release experiments conducted in April and those not parenthesized to the same carried out in May.

(b) Off Niigata Prefecture.

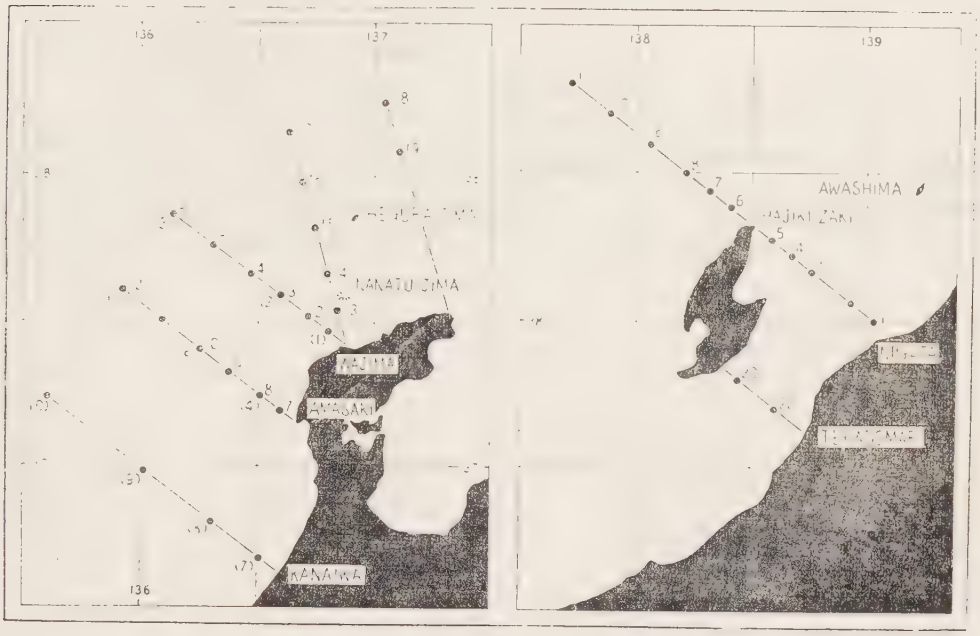

Fig. 1 Showing the location of drift bottle release stations.

新潟県～青森県西岸までの地域に漂着しているものも9％に過ぎない。半数近い47％が北海道西岸を北上してその沿岸に漂着している。新潟県沖合で実施のものについてみると，佐渡海峡内で投入したものでは，その80％が新潟県～青森県西岸に漂着しており，弾崎南東10浬の地点である投入点4からのものでは南下し両津湾内に漂着したものが少数ある。弾崎北西線で投入したものでは，青森県西岸までの地域に30％で比較的少く，70％が北海道西岸域，津軽海峡，さらに海峡を流出して太平洋岸に漂着している。ここで注目されるのは，新潟県～青森県西岸の地域に漂着しているものは，弾崎北西 5，35，45mile の地点からのものであり，10，15，25mile の各地点からのものは1本もないという事実である。これは沖合寄りの投入点10，11はひとつの渦流域内に位置しており，この附近には南東方に迂回接岸する流れが存在することを暗示している。

5月能登北西岸で投入したものでは，4月と異り，富山湾への流入漂着したものが目立つて多く，沿岸，沖合を合計した全投入域のもので，その50％が流入漂着している。これは北西に偏した向岸風によつて圧流されたものではないかと考えられるので，当時の気象状況を対比してみると，投入域にもつとも近い輪島測候所における観測資料[3]によれば，投入時の5月24日～26日さらに31日までの間では W～SW の風が圧倒的に多く，向岸風である N～NW 系の風のあつたのは25，31日の両日のみで，最大風速はそれぞれ 7.3，4.2m/sec，平均風速は 3.3，2.4m/sec であつて，他の風向系からそれほど卓越していたとは考えられない。また，その前後の数日間においてもかくべつ異つた状況はみられず，むしろこの季節に普通な SE～SW 系風が卓越していた。したがつて，この場合は風による圧流とは考えられず，海流自身の富山湾への流入が強勢になつてきたためであろうと推定されるのである。新潟県以北の北部地域へ漂着しているも

のは，沿岸域からのものが40%，沖合域からのものが60%で，沖合域からのものが沿岸域のものに比してやや多い．新潟県沖合で実施の佐渡海峡内で投入したものでは，秋田県～青森県西岸の地域にその50%が漂着しており，佐渡外浦域のものは津軽海峡西口（竜飛埼）以東および北海道沿岸に漂着しているものが，合せて65%を占めている。ここでも4月同様に最沖合点である投入点番号11（弾埼北西 45mile）のものは南東に迂廻しながら接岸し，青森県西岸以南の地域に漂着したものとみられる。

Table 1. Recovery of drft bottles dy release

(a) Released April 26–28 off-shore the NW coast of Noto Peninsula

Station number	Number of bottles released	Localities of discovery						
		Open sea coast of Noto Penin.	Toyama Bay		Niigata Pref.		Yamagata Pref.	Akita Pref.
			Ishikawa Pref.	Toyama Pref.	Honshu side	Sado Isl.		
1	47	0	4	1	1	1	2	2
2	50	0	0	0	0	0	0	0
3	50	0	0	0	0	0	0	0
4	50	0	0	0	1	0	0	
5	49	0	0	0	0	0	0	0
6	50	0	0	0	0	0	0	0
7	50	16	1	2	1	0	2	0
8	50	0	0	0	3	2	0	3
9	49	0	0	0	0	0	0	0
10	50	0	0	0	0	1	0	0
Total	495	16	5	3	6	4	4	6

(a′) Released April 19–20 in the Sado Straits and off-shore the Promontory of

1	20			1	0	1	1
2	20			0	0	0	2
3	20			0	0	0	1
4	20			0	2	0	0
5	20			0	0	1	0
20	20			1	6	0	0
22	20			0	0	1	2
6	20			0	0	2	0
7	20			0	0	0	0
8	20			0	0	0	0
9	20			0	0	0	0
10	20			0	0	0	1
11	20			0	0	0	2
Total	260			2	8	5	9

6月に実施したものは，新潟県沖合のみであり，佐渡海峡内で投入したものについて，その漂着の割合をみると，新潟県～山形県の沿岸で34%を占め，津軽海峡西口以東および北海道沿岸へ運ばれたものも比較的多く，それぞれ35%，21%に当つている。佐渡外浦域で投入したものでは，その80%以上が津軽海峡内に漂着しており，他の地域へは極めて小数である。

position and by localities of discovery.

Western coast ot Aomori Pref.	Hokkaido		Tsugaru Channel		Pacific Ocean			Sum of recovered bottles	Percentage ratio of recovery
	Japan Sea Coast	Okhotsk Sea coast	Honshu csoat	Hokkaido coast	Hokkaido coast	Aomori Pref.	South of Iwate Pref.		
3	0	0	1	1	1	1	1	19	40%
1	3	1	1	2	1	0	0	9	18
1	9	2	0	0	1	0	0	13	26
6	2	0	1	0	8	0	0	19	38
0	2	1	0	0	0	2	0	5	13
0	1	0	0	1	0	1	0	3	6
0	0	0	3	0	0	1	0	26	52
3	5	0	1	3	1	2	1	24	48
0	4	0	3	5	0	1	2	15	38
3	6	1	5	3	0	1	0	20	40
17	32	5	15	15	12	9	4	153	31.0

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1	1	0	1	0	1	0	0	7	35
0	0	0	0	0	0	0	0	2	10
2	1	0	0	0	0	1	0	5	25
0	0	0	0	0	0	1	0	3	15
2	0	0	0	0	0	0	0	3	15
1	0	0	1	0	0	0	0	9	45
0	0	0	0	0	0	0	0	3	15
3	1	0	1	0	0	0	0	7	35
0	0	0	2	0	0	0	0	2	10
0	2	0	0	0	2	1	0	5	25
0	0	0	1	1	1	5	0	8	40
1	0	0	0	1	1	0	0	4	20
1	0	0	1	0	0	1	0	5	25
11	5	0	7	2	5	9	0	63	21.2

(b) Released May 24–26 off-shore the NW coast of Noto Peninsula

Station number	Number of bottles released	Localities of discovery						
		Open sea coast of Noto Penin.	Toyama Bay		Niigata Pref.		Yamagata Pref.	Akita Pref.
			Ishikawa Pref.	Toyama Pref.	Honshu side	Sado Isl.		
1	50	0	9	0	3	0	2	1
2	50	0	10	3	5	0	0	1
3	50	0	11	2	1	0	0	2
4	50	0	19	3	1	0	0	5
5	38	0	0	0	0	0	0	3
6	20	0	0	0	0	0	0	1
7	20	0	5	1	1	1	0	0
8	20	0	2	0	1	0	0	0
9	20	0	4	0	1	0	0	0
10	20	0	2	1	0	0	0	0
11	20	0	8	1	0	0	0	0
12	20	0	0	1	1	0	0	0
13	20	0	7	0	2	0	0	0
14	20	0	11	2	1	0	0	0
15	20	0	2	0	5	0	0	1
16	20	0	0	0	0	0	0	0
17	20	0	0	0	0	1	0	0
18	20	0	0	0	0	1	0	1
19	20	0	0	0	0	0	0	0
Total	518	0	90	14	22	2	2	15

(b′) Released May 9–10 in the Sado Straits and off-shore the Promontory of Ha-

1	20				0	0	0	9
2	20				0	0	0	7
3	20				0	0	0	5
4	20				0	0	1	4
5	20				0	0	1	0
20	20				1	0	1	0
22	20				1	0	0	0
6	20				0	0	0	0
7	20				0	0	0	1
8	20				0	0	0	1
9	20				0	0	0	0
10	20				0	0	0	0
11	20				0	0	3	0
Total	260				2	0	6	27

Western coast of Aomori Pref.	Hokkaido		Tsugaru Channel		Pacific Ocean			Sum of recovered bottles	Percentage ratio of recovery
	Japan Sea coast	Okhotsk Sea coast	Honshu coast	Hokkaido coast	Hokkaido coast	Aomori Pref.	South of Iwate Pref.		
1	1	1	4	2	1	1	2	28	56%
1	1	0	0	3	1	0	0	25	50
0	1	0	0	1	1	1	0	20	40
1	0	0	0	0	0	0	0	29	58
0	0	0	5	1	0	1	2	12	32
0	0	0	0	0	0	0	0	1	5
0	0	0	0	0	0	0	0	7	35
0	0	0	0	1	0	0	0	4	20
1	0	0	0	0	0	0	0	6	30
0	1	0	1	0	0	1	0	6	30
0	0	0	0	0	0	0	0	9	45
0	0	0	0	0	0	0	0	2	10
0	0	0	1	0	0	0	0	10	50
1	0	0	0	0	1	0	0	16	80
0	0	0	0	2	0	0	0	10	50
1	0	0	2	2	0	0	0	5	25
0	0	0	2	0	0	0	0	3	15
2	0	0	5	0	0	0	0	9	45
2	1	0	1	0	0	0	0	4	20
10	5	1	21	12	4	4	4	206	40.0

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5	0	0	1	0	0	0	0	15	75
4	0	0	5	0	1	0	0	17	85
1	2	0	1	0	0	1	0	10	50
2	6	0	0	0	0	1	0	14	70
3	2	2	1	1	0	2	1	13	65
1	0	0	1	2	0	0	0	6	30
0	0	0	3	1	1	0	1	7	35
2	5	0	1	1	0	0	0	9	45
4	1	0	2	0	0	0	1	9	45
1	1	0	0	1	1	0	0	5	25
1	5	0	3	0	0	0	0	9	15
0	1	0	1	0	1	0	0	3	15
1	2	0	1	0	1	0	0	8	40
25	25	2	20	6	5	4	3	125	48.0

(c) Released June 5 in the Sado Straits and off-shore the Promontory of Hajikizaki.

Station number	Number of bottles released	Localities of discovery						
		Open sea coast of Noto Penin.	Toyama Bay		Niigata Pref.		Yamagata Pref.	Akita Pref.
			Ishikawa Pref.	Toyama Pref.	Honshu side	Sado Isl.		
1	20				0	0	0	0
2	20				0	0	10	0
3	20				0	0	0	0
4	20				0	0	0	0
5	20				0	0	0	0
6	20				0	0	0	0
7	20				0	0	0	0
8	20				0	0	1	0
9	20				0	0	0	0
10	20				0	0	0	0
11	20				0	0	0	0
Total	220				0	0	11	0

Table 2. Recovery of drift bottles by location of release and by localities of discovery.
April

Location of release		Localities of discovery						
		Open sea side of Noto Penin.	Toyama Bay	Niigata to Yamagata	Akita to western coast of Aomari	Western coast of Hokkaido to Okhotsk Sea	Tsugaru Channel	Pacific Ocean
NW coast of Noto Peninsula	Whole region	11%	5%	9%	15%	24%	20%	16%
	Coastal region	17	8	13	20	11	13	18
	Off-shore region	0	0	2	7	47	30	14
Off Niigata Prefecture	Whole region			6	41	8	14	22
	Sado Straits			6	50	6	6	9
	Off-shore the Promontory of Hajikizaki			7	26	10	23	35

Western coast of Aomori Pref.	Hokkaido		Tsugaru Channel		Pacific Ocean			Sum of recovered bottles	Percentage ratio of recovery
	Japan Sea coast	Okhotsk Sea coast	Honshu coast	Hokkaido coast	Hokkaido coast	Aomori Pref.	South of Iwate Pref.		
0	2	0	1	1	2	0	0	6	30%
0	0	1	0	1	0	1	0	13	65
2	2	0	0	1	0	0	0	5	25
1	0	0	2	0	0	0	0	3	15
0	1	0	0	0	1	0	0	2	10
0	1	0	2	1	0	0	0	4	20
0	0	0	2	0	0	0	0	2	10
1	0	0	1	0	0	0	0	3	15
0	0	0	2	0	0	0	0	2	10
0	0	0	5	0	0	0	0	5	25
0	0	0	1	0	0	0	0	1	5
4	6	1	16	4	3	1	0	46	20.9

May

	Location of release	Localities of discovery: Open sea side of Noto Penin.	Toyama Bay	Niigata to Yamagata	Akita to western coast of Aomori	Western coast of Hokkaido to Okhotsk Sea	Tsugaru Channel	Pacific Ocean
NW coast of Noto Peninsula	Whole region	0%	50%	13%	12%	3%	16%	6%
	Coastal region	0	58	15	7	3	10	7
	Off-shore region	0	41	10	19	2	23	5
Off Niigata Prefecture	Whole region			6	41	22	21	10
	Sado Straits			6	50	15	19	10
	Off-shore the Promontory of Hajikizaki			7	26	35	23	9

June

	Location of release	Localities of discovery: Open sea side of Noto Penin.	Toyama Bay	Niigata to Yamagata	Akita to western coast of Aomori	Western coast of Hokkaido to Okhotsk Sea	Tsugaru Channel	Pacific Ocean
Off Niigata Prefecture	Whole region			24%	9%	15%	43%	9%
	Sado Straits			34	10	21	21	14
	Off-shore the Promontory of Hajikizaki			6	6	6	82	0

II 表層流の考察

海流瓶の漂流を決定するものは，もちろん水の流れと風とであるが，その各々は，平均流と変動流とからなつているとみることができる。短時日における個々の漂着については，実際にその場所を吹く，たえず変動する風による圧流が最大の因子と考えられるが，春～夏にかけての長期間にわたる漂流を考察する場合には海流および風の変動部分はともに0に近づき，海流瓶の漂流は定常的な流れをほぼ反映しているとみてよいであろう。したがつて，前節においてのべた，海流瓶の漂着状況に基いて，日本海北部海域における春季の表層の流れを推定してみた。結果は模式的に Fig. 2—(a), (b), (c) のごとく示される。

まず沿岸域における流れについてみると，これは4月には能登外浦の 5 mile 沖を中心としてごく沿岸を流れ，禄剛埼寄りに富山湾に流入して佐渡海峡を北上していたと考えられ，巾もせまく流速も小さかつた。5月下旬になると，能登西方では Table 3 からわかるように，沿岸流はかなり広範囲に沖合にまで拡がり，禄剛埼附近で収斂して富山湾に強勢に流入している。これは対馬暖流が強勢となつたことを物語るものであろう。一方，禄剛埼附近で富山湾に流入する流れのほかに，それから分岐して佐渡海峡，あるいは佐渡外浦沿岸に向つている流れがあつた。これは弱勢なものであるが5月には4月に比してやや強さを増しているようである。

能登北西岸における沖合域の流れは北東に向い，佐渡沖合を通つて入道埼～津軽海峡西口附近で収斂して陸岸に近づく。この沖合域の流れは，佐渡沖合（弾埼北西方約 50mile）で一部が南東に迂廻し粟生島の周辺で佐渡海峡を北上してきた流れと合流し，沿岸に沿つて北上している。このことはすでに前述したように，弾埼北西線で投入した海流瓶のうちで4，5月ともに，最沖合点である第11点で投入のものが，沿岸寄りで投入したものに較べて，その漂着地域が南に偏していたことから推定されるのであるが，当時における力学的海流図[4]から佐渡弾埼沖合に反時計廻りの渦流域が存在しているのが認められるのと符合する。しかし，この渦流域は6月上旬の投入結果では確認されず，おそらく消滅あるいは，沖合に衰退したのではないかと考えられるが，これに関連して，入道埼沖の冷水域が4月下旬頃には平年並に強くなつて5月にも継続して存在したが6月上旬には再び弱くなつたという下村の報告[5]のみられることは興味深い。

津軽海峡西口に達した流れについては，一部は津軽海峡に入り，更に太平洋に流出するが，これには，三陸の沿岸に沿つて南下するものと，北海道著しく北方寄りに向い噴火湾に流入するものとがある。三陸沿岸を南下するものは比較的明瞭に現われており，八戸埼まで達することが知られ，また，北海道南東岸の流れは襟裳岬附近まで達する模様である。

一方，津軽海峡西方域において分岐した一部は奥尻島沖合を北上しつづけ神威埼附近で一分岐流を石狩湾に出し，残りの水はそのまま北上し，利尻，礼文島附近に達し，宗谷海峡を通り抜け，さらにオホーツク海を南下して斜里沿岸に達している。佐渡弾埼北西線で投入した海流瓶のうち根室海峡を抜けたと考えられるもので，北海道十勝沿岸に漂着しているのがあることは注目される。

津軽海峡西口において分岐する表層水のうち北上する部分と，海峡に流れこむ部分との割合を推定するために，能登北西岸で投入した海流瓶について，巨岸別に津軽海峡西口域まで達したものを，それぞれ 100 としてみると，その割合は Table 4 に示したようになる。

4月投入のものでは，沿岸域の 5～10mile までのものは津軽海峡に流入したものが多く，約 20mile 以沖のものでは北上と海峡への流入が相伸ばしている。5月投入のものでは北海道西岸への北上は極めて少く，大部分が海峡内に流入している。

能登北西岸で投入したもので津軽海峡西口附近に達するまでの経過（漂流）日数は（Fig. 2 参照）4月投入のものでは 30 日前後，5月投入のものでは 40 日前後であることから推して，問題の時期は5月下旬～6月上旬，7月上旬～7月中旬頃となる。津軽海峡西口沖における分岐境界域を巨岸 30mile 前後* とする

* 津軽海峡西方域における昭和30年6～7月の北海道西岸への北上流と津軽海峡への流入との分岐境界については前子川，宮崎[6]は樺太西沖では 5 mile 附近であるとし，田名部[7]も同様 30mile 附近を流向，流速の変化区域であると指摘している。

Fig. 2-(a) Patterns of surface flow in April inferred from the drift bottle experiment results along with the location of important recovegy spots. Figures show time in days spent for drift to respective spots.

Fig. 2-(b) Patterns of surface flow in May inferred from the drift bottle experiment results along with the location of important recovery spots. Figures show time in days spent for drift to respective spots.

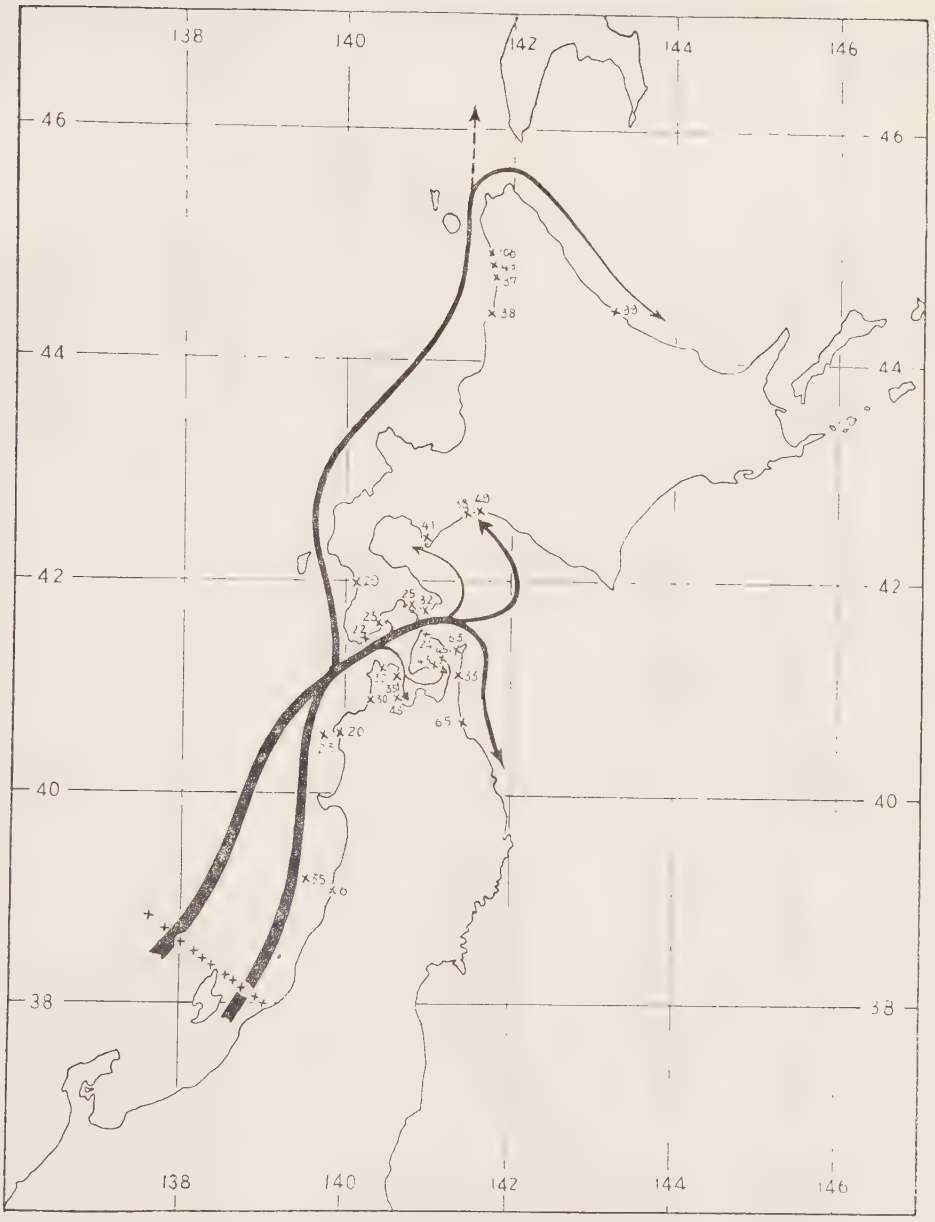


Fig. 2-(c) Patterns of surface flow in June inferred from the drift bottle experiment results along with the location of important recovery spots.
Figures show time in days spent for drift to respective spots.

と，4月下旬能登北西岸を起点としてみた場合，沿岸域を除いた表層の流れは佐渡のかなり沖合を北上し，津軽海峡西口においては，西方 30mile 前後のところに達しており5月下旬の場合については，4月下旬に較べて沿岸寄りに北上しており，津軽海峡西口においては巨岸 30mile 以内にあつたとの推定が可能である。

III マイワシ卵・稚仔の移行

マイワシの卵・稚仔の海中における浮游状態は各発生段階によつて，それぞれ異つた分布型を示すが，これは海上が極めて静穏な状態の場合だけであつて，実際には水塊の流動状態の時間的，空間的変化およびその程度によつて，卵群の垂直分布はさまざまに変形され，きわめて複雑な様相を呈する。しかし，卵全体としては表層に多く，深度を増すにつれて減少するという一般的傾向がある。稚仔については，前期稚仔は中層に多いがせいぜい 30m 附近までである。後期稚仔は表層～下層まで広く分布し，かなりの日週期的垂直移動を行うことが推考されている[8]。このように実際のマイワシ卵・稚仔の垂直分布は場所，時期，さらに発生段階によつて異り，きわめて複雑であるが，一般的命題としてはその移動は表層の流れによつて支配されているということができる。

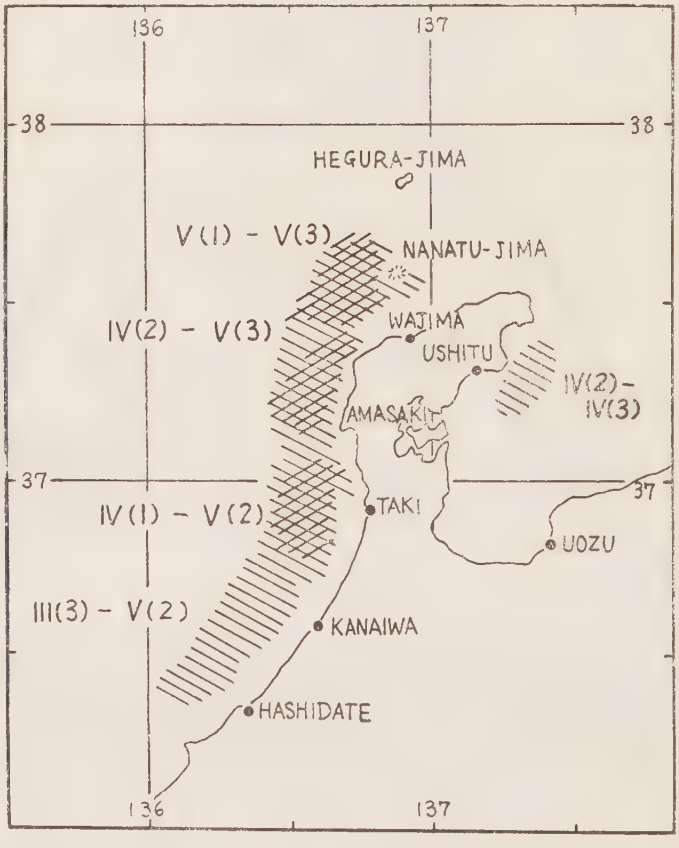


Fig. 3-(a) Schematic representation of the sardine spawning grounds in neighboring waters of Noto Peninsula, with their respective occurrence season in 1955. The distribution of spawning ground is shown in hatched patches; the arabic figures attached indicate month of occurrence with (1), (2) and (3) referring to the first, the second and the third ten days of the month respectively.

昭和30年度の日本海北部海域におけるマイワシの産卵場，産卵時期について，石川，新潟，山形，秋田，青森各県水試の昭和30年イワシ調査報告資料に基いて模式的に示せば Fig. 3 のようになる。図に示されているように，その期間は4月～6月上旬にわたり，また，それがおこなわれた海域は富山湾々奥部を除き石川～青森県西岸にいたる広範囲であるが，しかし，大量に産卵のおこなわれたのは沿岸に限られている。とくに能登周辺における卵・稚仔の分布について細かくみると Fig. 4 に示したようであつて，相対的に卵・稚仔の多いのは4，5月とも沿岸寄りであり，北岸域では七ツ島周辺つやや沖合に拡つている

以上の諸点を考慮に入れて，今季日本海北部海域における卵・稚仔の移行について推定してみる

能登周辺で4月に産卵されたもののうち，ごく沿岸寄りのものは，主として富山湾に流れこみ，一部は佐渡海峡附近に流されたであろうと推定される おなじく5月に産卵されたものは，そのほとんどが富山湾内へ運ばれたと考えられる 富山湾内に運ばれたものは6～9月の間反時計廻りの湾流[9]によつて湾内に長く停滞したであろう。佐渡海峡附近にまで流されてきたもの，および新潟県の各地沿岸において産卵されたものは，海流瓶の漂流結果からも明らかなように，比較的単調な流れのために同一海域に長く停滞することなく，漂流を続け，男鹿半島周辺の渦流域に一時停滞するであ

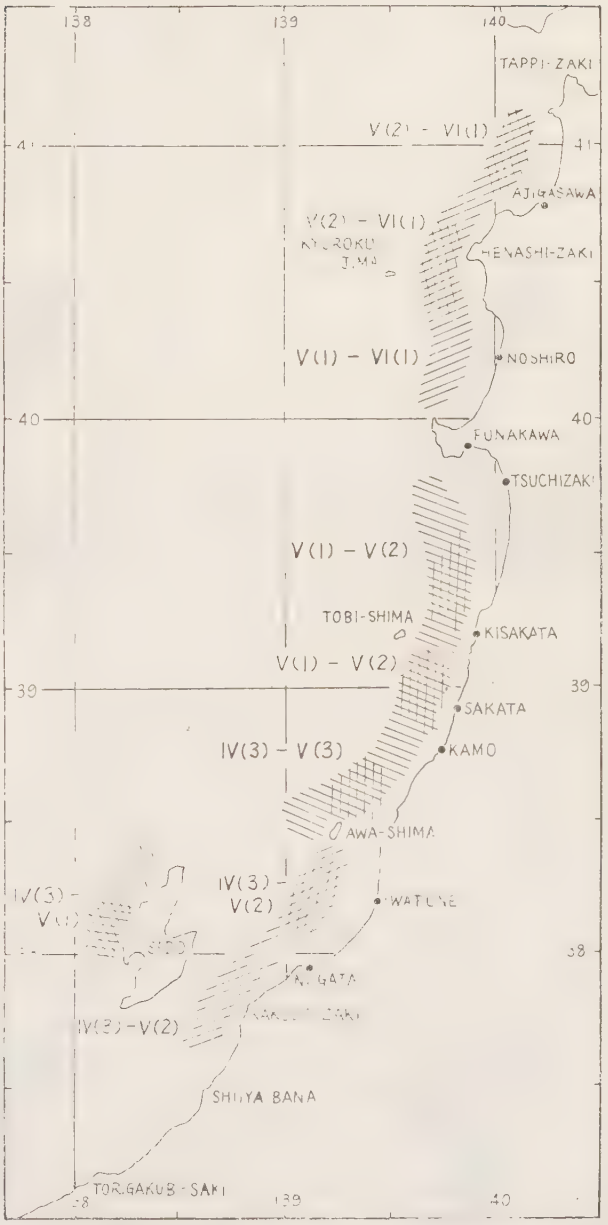


Fig. 3-(b) Schematic representation of the sardine spawning grounds in waters north of Niigata Prefecture, with their respective occurrence season in 1955. For explanation see Fig. 3-(a)

Table 3. Recovery of drift bottles released off northwestérn coast of Noto Peninsula.

(a) Released in April

(Miles)	Localities of recovery		
	Toyama Bay	Sado Straits	Far off western entrance to Tsngaru Channel
5 >	18%	16%	24%
10 >	0	5	90
20 >	0	9	76
25 >	0	0	100
35 >	0	0	100
45 <	0	0	99

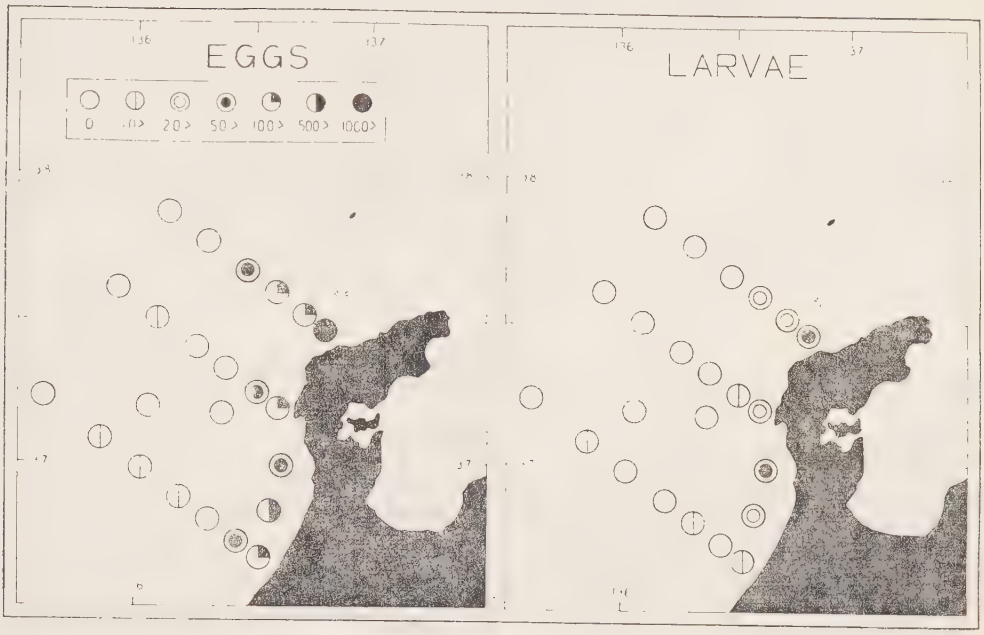
(b) Released in May

(Miles)	Localities of recovery		
	Toyama Bay	Sado Straits	Far off Western enteance to Tsugaru Channel
5 >	40%	17%	37%
10 >	56	21	20
20 >	71	7	17
25 >	60	13	13
35 >	30	0	60
45 <	6	0	60

Table 4. Partition at the western entrance to the Tsugaru Channel of drift bottles released off the northwestern coast of Noto Peninsula.

(Miles)	April		May	
	Western coast of Hokkaido	Tsugaru Channel	Western coast of Hokkaido	Tsugaru Channel
5 >	0%	100%	17%	83%
10 >	20	80	14	86
20 >	43	57	20	80
25 >	60	40	0	100
35 >	27	73	0	100
45 <	61	39	25	75
Mean	41	59	10	90

APRIL 26-28, 1955



MAY 24-26, 1955

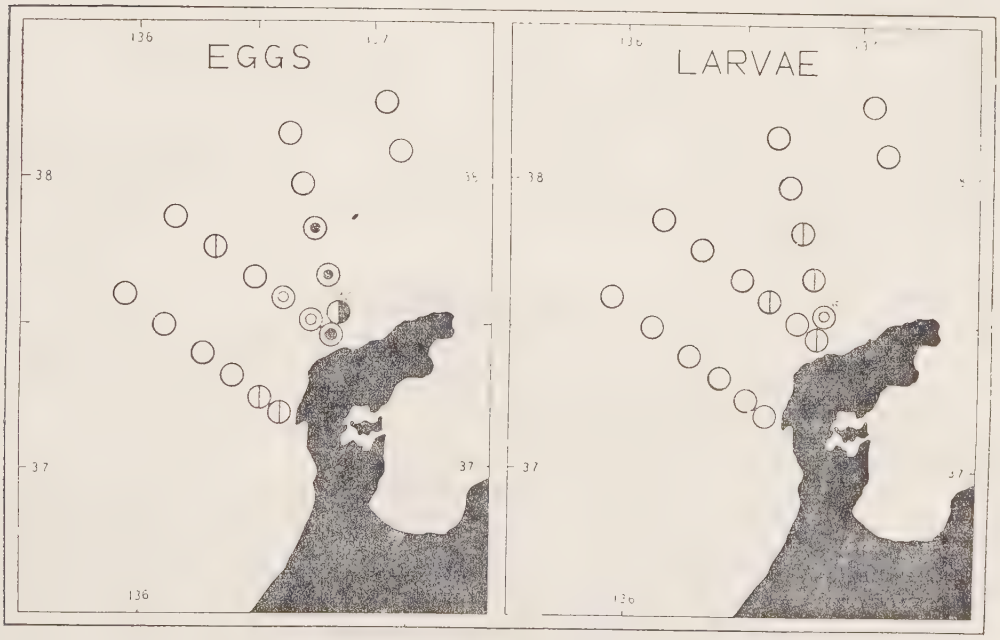


Fig. 4 Distribution of sardine eggs and larvae in waters adjacent to Noto Peninsula.

ろうが，さらに北上し，津軽海峡附近にまで運ばれるであろう。津軽海峡西方域における，北海道西岸への北上と，海峡への流入の境界域は前述したように西岸 [illegible]mile 附近であり，また，能登北西岸の沿岸域，佐渡海峡内で投入した海流瓶は，そのほとんどが津軽海峡内に流入していることから考えて，卵・稚仔は北海道西岸へ運ばれるものは，きわめて少く，その大部分が海峡内に流れこみ，一部は陸奥湾に，一部は噴火湾に，さらに一部は本州太平洋岸に沿つて南下するものと推定される，ただしその移流の割合はその年の海況によつて異るであろう。

漂流中，後期稚仔からカエリにいたつたものは次第に遊泳力を有するようになつて，生理，生態的要求から陸水の影響があり，かつ，淀みのある環境域に停滞するようになるものであろう。小イワシが漁獲されるのは，主としてこのような条件を備えた場所である。

Ⅳ 要　　約

昭和30年度能登近海のイワシ産卵調査と併行して，海流瓶を投入し，春季日本海北部海域の表層流の調査を実施した。

1）能登北西岸における沿岸流は，4月にはごく沿岸部を流れ，富山湾への流入は弱かつた。5月には能登西方では沖合まで広範囲に拡がり，禄剛崎附近で収斂して富山湾に強勢に流入していた。

2）沖合域の流れは北東に向い，佐渡沖合を通つて，入道崎～津軽海峡西口附近で収斂して陸岸に近づく。

3）前記沖合域の流れのうち，一部は佐渡沖合（弾崎北西約 50mile）で南東に迂廻し，粟生島の周辺で佐渡海峡を北上してきた流れと合流し北上していた。しかし，この流れは6月上旬には確認されなかつた。

4）4月能登北西岸における，沿岸域の 5～10mile 附近の表層流は主として津軽海峡に流入し，約 20mile 以上の沖のものでは，北上と海峡への流入とが相伸ばしている。5月では北海道西岸への北上はきわめて少量で大部分が海峡内へ流入するものと推定された。

5）マイワシ卵・稚仔の移行については，4月能登周辺で産卵されたもののうち，沿岸寄りのものでは富山湾に流れこみ，一部は佐渡海峡附近に運ばれたと推定される　5月に産卵されたものは，そのほとんどが富山湾内に運ばれたと考えられる。

6）能登周辺で産卵されるもので，佐渡海峡附近に運ばれたもの，あるいは，新潟県以北の海域において産卵されたものは，主として津軽海峡に流入し，一部は陸奥湾に，一部は噴火湾に，そして一部は本州太平洋沿岸に運ばれると推定された。

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表層流調査に用いられる海流瓶と海流封筒の効果比較について

笠　原　昭　吾

Some Considerations regarding the Use of Drift Envelopes for the Investigation of Surface Ocean Currents, with Special Reference to their Quality as Compared with that of Drift Bottles

By

Shôgo KASAHARA

Abstract

With the aim to study on the quality of the drift envelopes as a measure for surface ocean currents, a series of its release experiments were carried out off Noto Peninsula, Japan Sea, in the springs of 1955 and 1956, in addition to the liberation of conventional drift bottles.

I. The drift envelopes used in 1955 were made of vinir cloth 0.01 mm thick and sealed up by the single process of high-frequency electrical machining with a post card as well as a small steel ball as a weight inserted. These envelopes gave very unsatisfactory results.

II. The envelopes used in 1956 were made of vinir cloth 0.1 mm thick and sealed up by the double process of high-frequency electrical machining with a post card and without the steel ball inserted. The results obtained are summarized as follows.

(1) Rate of recovery was 33.7 percent for drift envelopes against 56.1 percent for drift bottles.

(2) From X^2-test, no significant difference was apparent in the frequency distribution of recovery by 10-day interval between the envelope and the bottle in five out of six operations.

(3) Inspections into the frequency distributions by time and by area of recovery as well as the estimated drift speed brought to the supposition that the envelope may be less influenced and less disturbed by wind stress than the bottle.

III. It is thus concluded that the drift envelope, when made of vinir cloth the thickness of which is more than 0.1 mm and sealed up by the double process of high-frequency electrical machining, would hold effective for a considerable long-period drift (viz., of three to four months) and that the envelope may yield a more reliable estimate of surface ocean currents than the conventional drift bottles.

緒　　言

漂流物による海流調査として海流瓶を用いての研究は古くから行われ，多大の効果をあげている。しかし，投入を大量に実施する場合にはその作製，取扱いに困難をきわめる。さらに，漂着結果から海流を推定するに当つては，風圧に基く瓶の運動を考慮に入れなければならないが，実際問題として海面直上の風向，風速を連続的に観測することは現在の段階では不可能であり，この点最大の欠陥を含んでいる。

海流封筒の取扱いが海流瓶と比較して軽便容易であり，漂流中も海面に密接して浮ぶので，風の影響はごく少いものと考えられる。米国ではかなり前から使用されており，わが国においても湖沼の流の調査として浜名湖で実施され良好な結果を得ている[1]また，外洋でも北洋の調査，黒潮流調査で使用されている。外洋で使用した場合，封筒そのものの耐浪性，拾得率等多くのことがらが問題とされる。海流封筒の使用に先だつて，これらの問題点が解明されなければならない。

筆者は1955年，1956年と能登近海のイワシ産卵調査に従事し，イワシ類の卵・稚仔の移行分布を確認するために表層流の調査を実施してきた。この調査の機会を利用して，海流瓶と海流封筒の効果の比較試験をおこない，その結果使用する海流封筒の規格及びその効果について若干の知見を得たので，ここに報告し参考に供したい。

なお，報告に先立ち，御指導ならびに御校閲を賜つた日水研資源部長加藤源治氏，同資源部伊東祐方，西村三郎両氏に対し深謝の意を表する。

I　1955年実施の結果について

1955年に使用した海流封筒は，淡紅色に着色した半透明のビニール製で，布地の厚さ0.01mm，封筒の接着は高周波ミシンによる一重接着で，海中において封筒が垂直に立つよう直径約 7mm の鋼鉄球を1個入れたものである。

4月26日から28日の間に能登西岸50マイルの範囲内に10点を設け，各点で海流瓶50本，海流封筒50枚を投入した。

成果について略述すれば，投入点15（金石 NW 5マイル）にて投入したもののうち8枚が石川県羽咋郡に漂着し，投入点11（海士崎 NW 10マイル）で投入したもののうち1枚は新潟県粟生島沖7マイルの海上で（投入41日後）拾得され，もう1枚は津軽海峡を流出して北海道勇払郡に漂着（投入後56日）したのみで，他の点で投入したものはまつたく漂着拾得の報告がなく，拾得率は海流瓶の31%に対して，この封筒では僅か2%に過ぎず，効果がきわめて不良であつた。

報告のあつた前記10枚の投入後漂着拾得されるまでの期間は，海流瓶と比較して大差は認められなかつた。

このように結果がきわめて不良であつた原因は，封筒そのものに不備な点があり，投入後時間の経過とともに封筒接着部位あるいはビニール膜そのものを通して海水が浸透したか，あるいは，耐浪性に乏しく漂流中に破損し浸水沈没した等の点が考えられる。

II　1956年実施の結果について

1. 使用した海流瓶並びに海流封筒

使用した流流瓶はビール瓶で，所要事項記入用のはがきを入れ，ゴム栓をした後ピッチで被い防水を強固にした。さらに発見されやすいように瓶の外側に白色ペンキで帯状に3線塗布した。

一方，海流封筒は淡紅色に着色した半透明のビニール製で，前記1955年の結果を考慮して膜の厚さを前年度の10倍の 0.1mm とし，さらに，開口部の密着は高周波ミシンにより，防水を強固にするために2重接着を施した。投入後海流封筒が海面に垂直に立つように，前回では封筒内に鉄球を入れたが，これはむしろ漂流中摩擦のために封筒の破損を極度に高め，同時に風の抵抗を受ける部分を大きくし，逆効果を生ずる

可能性が強いので今回は除いた。海流封筒の形状は長辺 16.0cm 短辺 10.0cm のものである。

2. 成果について

a) 拾得率について

海流瓶と海流封筒を併投したのは，主として鵜入 NNW 線であり，4月12日～5月21日の間に6回にわたつて実施した。第1回（4月12日）の投入は巨岸40浬内（沖合定線）であり，第2回以後は巨岸12浬以内（沿岸定線）で投入した。

投入月日別，投入点別の拾得率を示せば Table 1 のようになる。各回，各点とも拾得率は海流瓶の方が大きく，全体としては，海流瓶 56.1%，海流封筒 33.7% となり，さらに，海上で拾得されたものの割合は海流瓶では全拾得数の 25%，海流封筒では 11% となつており，海上で発見される割合も海流瓶に較べて海流封筒では低かつた。

Table 1. Recovery of drift bottles and envelopes by dates of release.

(1) Released on April 12 along the NNW line off Unyû

Station number of release position	Drift bottle			Drift envelope			B/A×100
	Number of released	Number of recovered	Percentage ratio of recovery (A)	Number of released	Number of recovered	Percentage ratio of recovery (B)	
1 (5M off)	30	22	73.4%	50	19	38.0%	51.9
2 (10 〃)	29	14	48.3	50	25	50.0	103.5
3 (20 〃)	30	14	46.7	49	19	38.8	83.2
4 (30 〃)	30	14	46.7	50	12	24.0	51.5
5 (40 〃)	30	13	43.4	50	6	12.0	27.7
Total	149	77	Mean 51.7	249	81	Mean 32.5	62.9

(2) Released on April 21 along the NNW line off Unyû

1 (1M off)	30	18	60.0%	50	18	36.0%	60.0
2 (6 〃)	30	15	50.0	50	23	46.0	92.0
3 (11 〃)	30	23	76.6	50	19	38.0	49.6
Total	90	56	Mean 62.2	150	60	Mean 40.0	64.2

(3) Released on April 28 along the NW line off Ôsawa

1 (2M off)	30	21	70.0%	50	19	38.0%	54.3
2 (7 〃)	30	15	50.0	50	15	30.0	60.0
3 (12 〃)	30	16	53.3	50	14	28.0	52.5
Total	90	52	Mean 57.8	150	48	Mean 32.0	55.4

(4) Released on May 5 along the NNW line off Unyû

Station number of release position	Drift bottle			Drift envelope			B / A × 100
	Number of released	Number of recovered	Percentage ratio of recovery (A)	Number of released	Number of recovered	Percentage ratio of recovery (B)	
1 (1M off)	30	20	66.7%	50	13	26.0%	39.0
2 (6 〃)	30	21	70.0	50	15	30.0	42.8
3 (11 〃)	30	14	46.7	50	24	48.0	102.8
Total	90	55	Mean 61.1	150	52	Mean 34.7	56.8

(5) Released on May 16 along the NNW line off Unyû

1 (1M off)	30	12	40.0%	50	14	28.0%	70.0
2 (6 〃)	30	21	70.0	50	23	46.0	65.6
3 (11 〃)	30	15	50.0	50	19	36.0	72.0
Total	90	48	Mean 53.3	150	56	Mean 37.4	70.2

(6) Released on May 21 along the NNW line off Unyû

1 (1M off)	30	20	66.7%	50	11	22.0%	33.1
2 (6 〃)	30	17	56.7	50	16	32.0	56.4
3 (11 〃)	30	11	36.7	50	13	26.0	71.0
Total	90	48	Mean 53.3	150	40	Mean 26.7	50.1
Grand total	599	336	Mean 56.1	999	337	Mean 33.7	60.1

b) 地域別漂着の割合について

投入月日別の漂着状況，表層流の推定については別途報告の予定なのでここでは省略する。

沖合定線（巨岸 40 浬）と沿岸定線（巨岸 12 浬内）に大別して，各地域への漂着の割合についてみると，Table 2 のようになる。これによると海流瓶，海流封筒の漂着の状況はほぼ同様な傾向を示しているが，入道埼以北の北部地域への漂着の割合は，沖合定線で投入したものは海流瓶の方が海流封筒よりも高くなつている。一方，沿岸定線で投入したものは海流瓶よりも海流封筒の方が高く逆の傾向がみられた。

なお，沖合定線で投入したものでは投入点ごとに，沿岸定線で投入したものについては投入月日ごとにそれぞれ最遠距離地へ運ばれたものについて示せば Table 3 のようになる。沖合定線のものでは海流瓶は海流封筒に較べて遠距離まで漂流していることがわかり，沿岸定線のものではほぼ似かよつた状況を示している。

c) 投入後の漂着数の変化について

投入してからの漂着の状況をみるために投入後の経過日数を 5 日間隔にとり，その拾得数の変化を Fig. 1 に示した。

Table 2. Recovery of drift bottles and envelopes by locations of release and by localities of recovery.

(1) Drift bottle

Location of release	Total number of recovered bottle	Localities of recovery								
		Ishikawa Pref.	Toyama Pref.	Niigata Pref.	Yamagata Pref. ~ Nyudo-zaki	Nyudo-zaki ~ Tappi-zaki	Japan Sea coast of Hokkaido	Tsugaru Channel	Pacific Ocean
Off shore region	77	1	0	33	8	8	1	11	15
		1.3%		53.2%		10.4%	1.3%	33.8%	
Coastal region	259	90	13	57	35	24	9	18	13
		35.5%		35.5%		9.2%	3.5%	12.0%	

(2) Drift envelope

Location of release	Total number of recovered envelopes	Localities of recovery								
		Ishikawa Pref.	Toyama Pref.	Niigata Pref.	Yamagata Pref. ~ Nyudo-zaki	Nyudo-zaki ~ Tappi-zaki	Japan Sea coast of Hokkaido	Tsugaru Channel	Pacific Ocean
Off shore region	81	0	0	35	20	11	1	12	2
		0.0%		67.9%		13.6%	1.2%	17.3%	
Coastal region	256	68	11	51	52	26	10	27	11
		30.9%		40.2%		10.2%	3.9%	14.8%	

Table 3. Some examples of long-distance drift.

(1) Off-shore region (Released on April)

Station number of release position	Drift bottle			Drift envelop		
	Place of recovery	Estimated distance of drift	Drift period	Place of recovery	Estimated distance of drift	Drift period
1 (5M off)	Kashima Dift., Ibaragi Pref.	725 (M)	134(day)	Higashitsugaru Dist., Aomori Pref.	340(M)	29 (day)
2 (10M off)	Kudô Dist., Hokkaidô	340	48	Nishitsugaru Dist., Aomori Pref.	280	27
3 (20M off)	Kitatsugaru Dist., Aomori Pref.	280	31	Yamakoshi Dist., Hokkaidô	420	91
4 (30M off)	Kashima Dist., Ibaragi Pref.	725	96	Kitatsugaru Dist., Aomori Pref.	270	50
5 (40M off)	Kashima Dist., Ibaragi Pref.	725	83	Muroran City, Hokkaidô	380	110

(2) Coastal region

Date of release	Drift bottle			Drift envelope		
	Place of recovery	Estimated distance of drift	Drift period	Place of recovery	Estimated distance of drift	Drift period
April 21	Yamakoshi Dist., Hokkaidô	420 (M)	89 (day)	Kisennuma Dist., Iwate Pref.	520(M)	73 (day)
April 28	Yamakoshi Dist., Hokkaidô	415	72	Yamakoshi Dist., Hokkaidô	420	67
May 5	Kamikita Dist., Aomori Pref.	415	54	Miyako City, Iwate Pref.	470	61
May 16	Kamikita Dist., Aomori Pref.	420	86	Shimokita Dist., Aomori Pref.	335	61
May 21	Kunohe Dist., Iwate Pref.	430	80	Tomakomai City, Hokkaidô	415	46

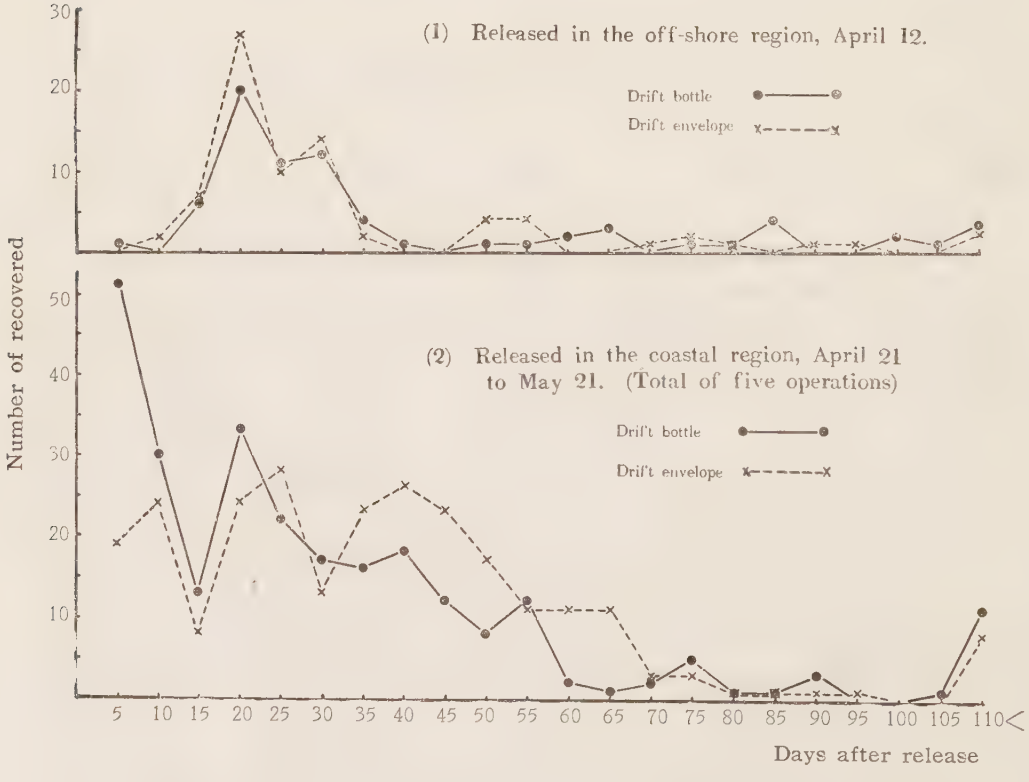
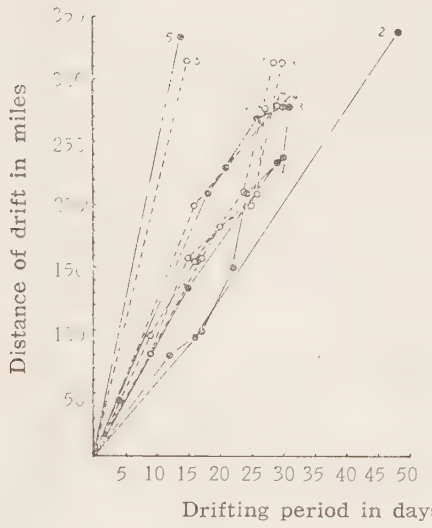
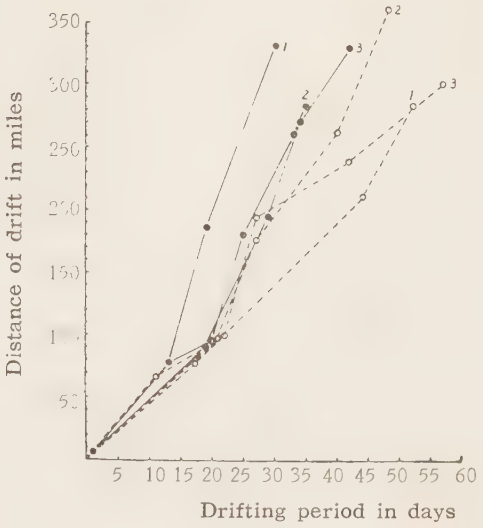


Fig. 1 Change in number of recovery with the lapse of time.

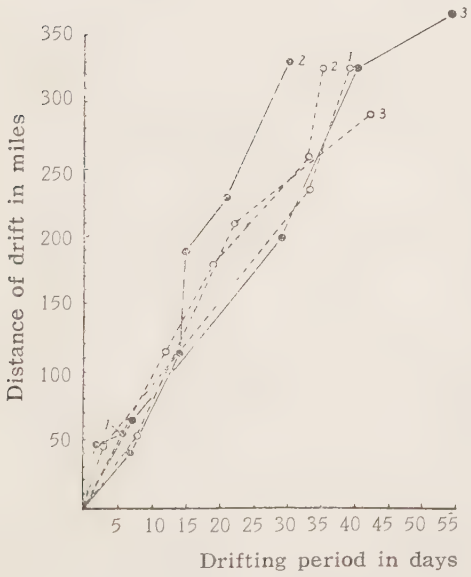
Fig. 2 Showing the relationship between the period and the distance of drift.
Drift bottle ●——● Drift envelope ○·····○



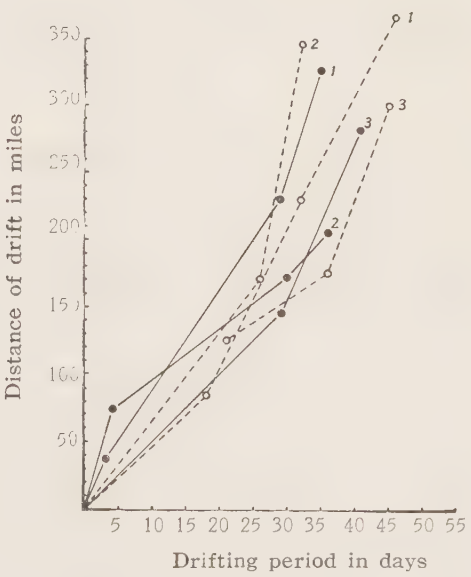
(1) Released on April 12 along the NNW line off Unyû



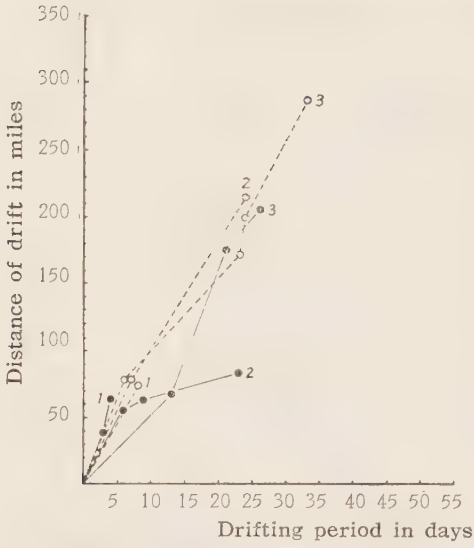
(2) Released on April 21 along the NNW line off Unyû



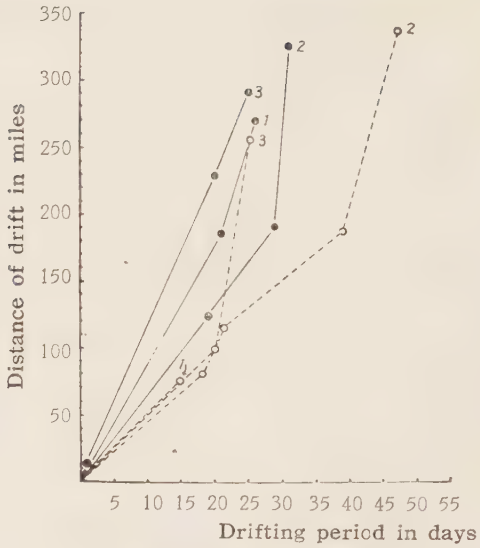
(3) Released on April 28 along the NW line off Ôsawa



(4) Released on May 5 along the NNW line off Unyû



(5) Released on May 16 along the NNW line off Unyû



(6) Released on May 21 along the NNW line off Unyû

4 月 12 日に投入した鵜入 NNW 40 浬の沖合定線のものでは〔Fig. 1—(1)〕，両者ともその漂着傾向はほぼ同一であり，投入後 16 ～ 20 日の間にもつとも多く漂着（主として佐渡海峡～新潟山形両県境間）し，その後，徐々に減少し，30 日以後は急激に減少している。沿岸域で投入したものを一括してみると〔Fig. 1—(2)〕，海流瓶では投入後 5 日間にもつとも多く拾得され（投入直後投入点附近の海域，あるいは飯田湾内），次いで 16 ～ 20 日の間に多く，その後は徐々に減少して 56 日以後に拾得されたものは全拾得数の 10% に満たない。海流封筒では海流瓶とはやや異り，投入直後に拾得されたものは海流瓶の場合のように顕著ではなく，投入後 40 日位までの期間は比較的平均して拾得されていることが目立つ，その後徐々に減少し，66 日以後は急激に減少し，その割合は全拾得数の 5% に過ぎない。

ここで，海流瓶と海流封筒について，投入してから漂着するまでの間に差があるかどうかを x^2 検定法を用いて吟味した。

この場合，漂着区間を狭くとるために，能登半島から入道埼までの区域を漂着区域とした。

海流瓶を (B_1)，海流封筒を (B_2) とし，投入後の経過期間は 10 日間隔とし，C_1, C_2……Cn で表わす。投入日別に分割表並びに計算[2] した結果を下表に示す。

第 1 次（4 月 12 日投入）

	C_1	C_2	C_3	C_4	Total
B_1	27	28	4	5	64
B_2	36	26	8	4	74
Total	63	54	12	9	138

$X^2 = 2.35$

第 2 次（4 月 21 日投入）

	C_1	C_2	C_3	C_4	Total
B_1	11	13	4	3	31
B_2	4	13	5	6	28
Total	15	26	9	9	59

$X^2 = 4.23$

第3次（4月28日投入）

	C_1	C_2	C_3	Total
B_1	27	5	3	35
B_2	8	7	3	18
Total	35	12	6	53

$X^2=5.78$

第4次（5月5日投入）

	C_1	C_2	C_3	Total
B_1	13	8	14	35
B_2	6	5	17	28
Total	19	13	31	63

$X^2=2.81$

第5次（5月16日投入）

	C_1	C_2	C_3	Total
B_1	25	7	11	43
B_2	26	10	11	47
Total	51	17	22	90

$X^2=0.37$

第6次（5月21日投入）

	C_1	C_2	C_3	Total
B_1	20	2	2	24
B_2	9	5	8	22
Total	29	7	10	46

ここに，$N=3$ ：$Pr\{X^2>7.81\}=0.05$

$N=2$ ：$Pr\{X^2>5.99\}=0.05$

であるから，海流瓶と海流封筒は同じ母集団からの無作為標本であるとの帰無仮設を検定すると，投入次の1，2，3，4，5については危険率0.05以下をもつて，両者の間において投入してから漂着するまでの状況に差がないことがいえる。投入次6の場合については分割表を一見して差のあることが解り，2以下の値が出ているので X^2 テストによる検定は行わなかつた。

d）推定平均漂流速度について

海流瓶と海流封筒の漂流速度を比較するために，投入日ごとに各投入点について，それぞれ，海上で拾得されたもの，あるいは，同じ地域に多数漂着したものについては，もつとも早く漂着したもので代表させて，横軸に漂流日数をとり，縦軸に推定漂流距離をとつて漂流曲線を描いてみると Fig. 2—(1), (2), (3), (4), (5), (6) のようになり，さらに，これから平均漂流速度を算出すると Table 4 に示したような結果となる。これによると，沖合定線で投入したものでは，漂流速度は海流瓶よりも海流封筒の方が大きく沿岸定線で投入したものでは，概ね海流瓶が海流封筒よりも大きくなつている。

今まで述べた地域別漂着の割合，投入後の漂着数の変化，推定平均漂流速度の結果によると，沖合域（第Ⅰ次4月12日投入）で投入したものについてみると海流瓶では北部域（入道埼以北の地域）へ漂着したものの割合は海流封筒に較べてやや大きく，平均漂流速度についてみると海流瓶＜海流封筒となつている。これは海流瓶では海流封筒に比して風圧の影響が大であることを物語るものと考える。即ち，調査実施の時期である春～夏季においては，日本海方面では北西の卓越風は衰え，比較的風向の変化が多い季節である。このために海流瓶ではジグザグな漂流経路をたどるものと考えれば，漂流距離を直線として最短距離をとつた場合において海流瓶の漂流速度が海流封筒より小であることも理解されよう。

沿岸域（第2，3，4，5，6次）で投入したものは，南部域（能登半島～入道埼以南の地域）での漂着の割合は海流瓶＞海流封筒となつており，漂流速度についても海流瓶＞海流封筒となつている。これは前述のように海流瓶では風の応力を受けることが海流封筒に比べて大きいために，比較的短時間でも W～N

系の風が吹くと，それによつて接岸圧流され，容易に海岸に漂着するものが海流封筒に較べて多く，漂流速度の大きいのも風圧による速度が加わつているためであり，海流封筒では海流瓶に較べて風圧による影響が少いことを示しているものと推定される。

Table 4. Estimated mean speed in the drift of bottles and envelopes.

(1) Off-shore (Released on April 12)

Station number of release position	Drift bottle	Drift envelope
1 (5M off)	9.6 M/day	10.2 M/day
2 (10M off)	6.7	9.2
3 (20M off)	7.7	9.2
4 (30M off)	10.8	11.0
5 (40M off)	23.0	21.6
Mean	11.6	12.2

(2) Coastal region

Date of release	Drift bottle	Drift envelope
April 21	7.2 M/day	5.7 M/day
April 28	11.0	9.6
May 5	8.5	7.0
May 16	8.0	9.1
May 21	9.7	5.9

Ⅲ 海流封筒の有効期間について

1955年の実施結果から海流封筒即ち，ビニール製のものについては，漂流中において封筒の破損，ビニール膜の海水の浸透等によつて浮游力を失い沈没してしまう可能性があると推察された。

1956年の実施に当つては前述したように，この点を考慮し，膜の厚さを10倍の 0.1mm にするとともに，はがきの拾得者記入事項欄に海流封筒内に水が入つていたかどうか，その状態についての回答を求めた，

その結果を整理したのが Table 5—(1) である。これによると，各回を通じて，海流封筒が完全で封筒内に水分を含んでいなかつたものが80% 以上であり，これについて回答のなかつた報告はがきの状態からは海水に濡れたと思われるものは1枚もなく，これを完全であつたものに加えると 90% 以上となる。一方，浸水又は，はがきに湿気を含んでいたものは全体の 10% 以下である。これについても浸水していたのはごく少数であつて，湿気を含んでいただけの状態のものが大部分であつた。

これについて，投入後どの位の日数を経過して封筒内に水分を含んだものが現われるか，その出現割合についてみると Table 5—(2) のようになる。

Table 5.

(1) State of the post card in the drift envelope when recovered.

Date of release	Dry and not damaged at all	Wet or damaged due to penetration of water	Unknown	Total
April 12	66 (81.5%)	14 (17.3%)	1 (1.2%)	81
April 21	50 (83.4%)	6 (10.0%)	4 (6.6%)	60
April 28	42 (87.4%)	4 (8.4%)	2 (4.2%)	48
May 5	45 (86.5%)	3 (5.8%)	4 (7.7%)	52
May 16	54 (96.4%)	1 (1.8%)	1 (1.8%)	56
May 21	36 (90.0%)	4 (10.0%)	0 (0.0%)	40
Total (Mean)	293 (87.0%)	32 (9.5%)	12 (3.5%)	337

(2) Occurrences of the wet post card by 10-day periods after release.

	Time in days from release to recovery									Grand total
	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–	
Total number of post cards recovered (A)	45	66	65	51	44	26	15	7	18	337
Number of wet post cards (B)	1	7	3	3	4	5	3	2	4	32
B/A (%)	2.2	10.6	4.6	5.9	9.1	19.3	20.0	28.0	22.0	9.5

もつとも早いものは投入後9～10日経過した間に1枚現われているが，これは投入後9日経過したものである。投入後の経過日数50日までの期間に出現したのは10%以下であり，以後経過日数をますにしたがつて，海水の浸透するものの割合は多くなるが，経過日数51～最終漂着経過日数約180日までにおいて30%以下である。全体としては封筒内に水分のあつたものは全拾得数の9.5%である。

以上のことからビニール膜の厚さを0.1mm，封筒の開口部の接着は高周波ミシンによつて二重に接着を施せば，漂流約半カ年間は封筒内に浸水又は湿気を含む状態のものが生ずるのは10%前後である。即ち，海流封筒の漂流有効期間は上記の規格のものであれば約半カ年以上と考えられ，沿岸部における表層流の調査としては充分使用に耐え得るものと考えられる。

Ⅳ 摘　　要

表層流調査としての海流封筒の効果をみるために1955年（4月1回），1956年（4，5月6回）に能登近海で海流瓶と海流封筒を同時投入して効果の比較を行つた。その結果は次のごとくである。

Ⅰ）1955年に使用した海流封筒はビニール製で膜の厚さ0.01mm，封筒の開口部の接着は高周波ミシンによる一重接着を施し，中に直径約7mmの鋼鉄球を1箇入れた。その結果はきわめて不良であつた。

Ⅱ）1956年に用いた海流封筒はビニール製で膜の厚さ0.1mm，開口部の接着は高周波ミシンにより二重接着を施したものである。それによる結果では，

(1) 拾得率は海流瓶の56.1%に対して海流封筒は33.7%でやや低い。

(2) 時間別漂着数について X^2 検定を行つたところ，実施回数6回のうち5回までは両者の間に危険率は0.05で差が認められない。

(3) 漂着の割合，時間別拾得数，推定平均漂流速度からみて風圧による影響は海流瓶よりも海流封筒では小さい。

Ⅲ) 結論として，海流封筒を使用する場合はビニール膜の厚さ 0.1mm 以上のものを用い，開口部の接着は高周波ミシンによつて二重接着を施せば，かなり長期（約半カ年）の漂流中においても破損，浸水を防止でき，表層流を推定するには海流瓶よりも妥当性があるものと推察された。

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エゾボラモドキ *Neptunea intersculpta* (SOWERLY) の毒性について*

平井正夫　神名孝一**

The poison of a shellfish, *Neptunea intersculpta* (SOWERLY).

Masao HIRAI and Kooichi KANNA

Neptunea intersculpta found in a deep sea of the Pacific and the Japan Sea have caused often poisoning.

We substantiated the fact that this poison exists only in the salivary gland and not in other parts. Judging from the behavior of mice applied with this poison, it seems to be a poison of paralytic form.

エゾボラモドキは日本海及び太平洋の比較的深海に棲息する北方系肉食性巻貝で，エゾバイ科 Buccinidae に属し，日本海西南海域においては機船底曳網に混獲され赤バイと俗称される．この貝は美味であるため食用に供されるが，しばしば中毒することがある。

さきに浅野りがヒメエゾボラについて同様な観察をしているが，その中毒症状には個人差があり，普通大人で貝1個を食すると30分から1時間位で視力低下し，順次酔い状態から悪感吐気を催す。通常この症状は2～3時間経過することにより平常に復する。従来この貝で人命を失つた者はない。

このエゾボラモドキの中毒は鮮度良好な物を煮熟して食して発現するので，腐敗による中毒とは認められず，生体に保有されているものと考えられる．著者等は有毒物存在位置及び毒性を明らかにしたので報告する。

方　　法

1. 試　　料

試料は兵庫県香住港に水揚げされた殻高 9～10cm，重量 99～144g のもの 20個で，各部分の割合は第1表のごとくである。

Table 1. Percentage of every parts

Height	Weight	Shell	Meat	Organ	Salivary gland
9.1～10.1cm	99～144g	48%	31%	18%	3%

試料の処理は生きている貝を割り，肉質部及び内臓部を取り出し，両者を分離した．肉質部はさらに切り開いて乳白色乃至淡黄色の唾腺 (Salivary gland) を分離した．各部位の解剖図は第1～2図のごとくである．

* 昭和31年度日本水産学会年会発表
** 東海区水産研究所

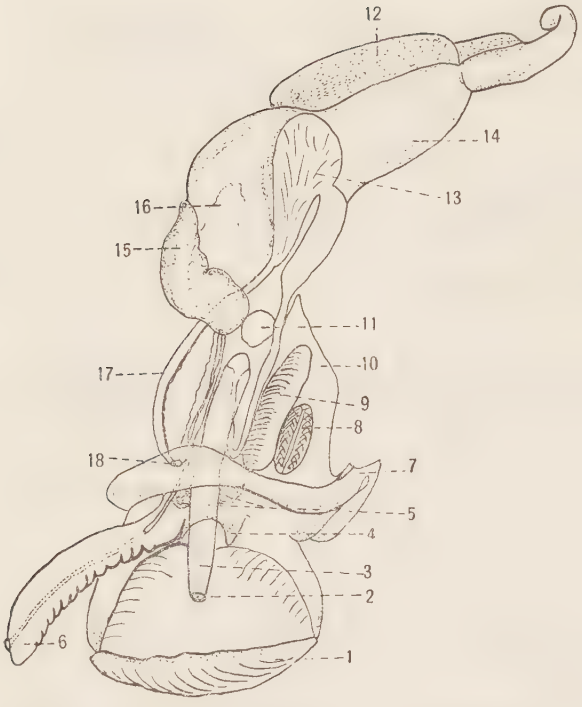

Figure 1. Lateral view of *Neptunea intersculpta* (SOWERLY).

(1) operculum (2) radula (3) proboscis (4) mouth (5) salivary glands (6) penis (7) respiratory siphon (8) osphradium (9) ctenidum (gill) (10) muscle (11) heart (12) gonad (13) stomach (14) digestive gland (liver) (15) renal gland (16) hypobranchial gland (17) rectum (18) anus

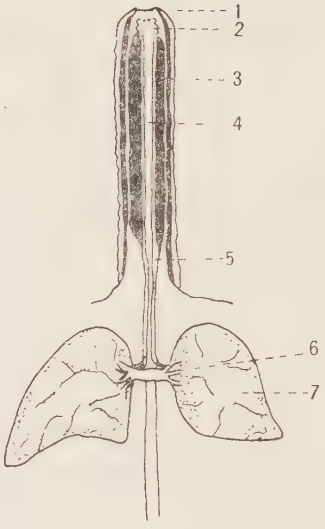

Figure 2. Diagram to illustrate the proboscis and alimentary canal of *Neptunea intersculpta* (SOWERLY).

(1) radula (2) pharynx (3) radular sheath, red colored (4) oesophagus (5)duct of salivary gland (6) oesophageal ring (7) salivary glands

2. 供試液の調製

肉質部，唾腺部及び内臓部の各部分はそれぞれ細切して，各部分ごとに中性メタノール約5倍量を加え，水浴上で冷却器をつけて30分間加熱して上澄液を採る，残渣は3回同様に処理抽出後，上澄液を集めて蒸発皿に入れ，60°C の水浴上で加温し，扇風機を使用してメタノールを除いた。残渣はエーテルで数回洗滌してエーテル可溶物を除去し，残存エーテルを水浴上で除去して茶褐色芳香を有するシラップを得た。このシラップを抽出試料の重量 10g に対し 1cc となるように蒸溜水を加え，濾過後アンプルに詰めて 100°C, 30分間加熱滅菌し，注射液を調製した。

3. 動 物 試 験

体重 20g 前後のマウスを使用し，供試液は原液そのまま，1/10及び1/100稀釈液の3種類とした。この各供試液はそれぞれ第2表に示すような量で腹腔内に注射して観察した。

Table 2. Feeding records of sample.

Mouse No.	Body Weight	Sex	Sample	Extracts injected		Weight of Sample used	Results
1	19.8	♀	Meat		0.50 cc	5.000g	Died after 2 min.
2	19.4	♂			0.10	1.000	No remarkable change.
3	18.0	♀		1/10	0.50	0.500	〃
4	17.0	〃		〃	0.25	0.250	〃
5	23.5	♀	Intestine	1/10	1.00	1.000	No remarkable change.
6	21.5	♂		〃	0.50	0.500	〃
7	20.6	♂	Salivary gland	1/10	0.50	0.500	Died after 1h25min.
8	20.0	♀		〃	0.25	0.250	〃 1h03min.
9	20.2	〃		〃	0.10	0.100	〃 3h50min.
10	15.8	♂		1/100	0.50	0.050	〃 2h07min.
11	19.0	♀		〃	0.50	0.050	〃 3h05min.
12	22.0	〃		〃	0.50	0.050	〃 5h30min.
13	12.2	♂		〃	0.25	0.025	〃 3h10min.
14	23.0	♀		〃	0.25	0.025	Eyes closed, Motor paralysis after
15	22.7	〃		〃	0.25	0.025	5min. Recovered after 30～60min.

結果及び考察

試験結果は第2表のごとくである。

A 肉質部供試液は異状を認められなかつたので，この部分には有毒成分はないことが判明した。ただし，衰中死亡した動物であるのは，腹腔内に注射された供試液中のエキス分が多量のためによると考えられ，その際麻痺症状は認められなかつた。

B 唾腺部を除く全内臓部の供試液は異状を認めなかつたので，この部分にも有毒成分のないことが判明した。

C 唾腺部供試液は実質 0.5g相当量を腹腔内に注入したのであるが，試験動物は供試液注入後，いづれも運動不能となり，時々身体を震わして痙攣を起し，フグ毒のように強くはないが，飛び上り遂に横臥して喘いで死亡した。また，致死量以下の 0.025g 相当では体重の少い動物は死亡し，20g程度の体重では運動不活発となり 30 分から 1 時間位経過すると回復し，以後病変は認めなかつた。すなわち，エゾボラモドキの有毒部分は唾腺に存在し，その毒性は麻痺性の物とみられる。この点浅野のヒメエゾボラの場合と同様である。

なお，毒の強さを比較する場合，毒の強さを臓器 1g で 20g 前後のマウス何匹を殺し得るかをもつて表すと便利である。

エゾボラモドキの場合は第2表に明かなように，0.5g の唾腺中に含まれている毒物質で，マウス1匹を殺し得るから，1g の唾腺では20匹を殺し得ることになる。すなわち，20M.Uである。

このように唾腺に麻痺性毒物質を含有する理由は従来からいわれているように採餌の際，餌料動物に毒液を注入することによつて，その運動を不能にし採食を容易にするためと考えられる。

なお，毒物質の化学的性質その他吟味すべき事項が多いので，究明でき次第発表する。

摘　　要

1. エゾボラモドキの毒性及びその所在を明かにした。
2. エゾボラモドキ毒成分は消化腺に附属する乳白色乃至淡黄色の唾腺（Salivary gland）に存在する。その毒は神経毒に類し，ヒメエゾボラの場合とほぼ同一のものではないかと考えられる。

終りに御協力を戴いた小川，伊藤両技官，東海区水研右田研究室の各位及び御校閲を戴いた日本海区水研内橋所長，野口，加藤両部長に感謝します。

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漁獲物の鮮度保持に関する研究（第6報）
2～3防腐剤の鮮度保持効果

山本常治・野口栄三郎

Studies on the freshness of fish (6)

On the effect of some preservatives on keeping quality of fishes.

Joji YAMAMOTO and Eizaburo NOGUCHI

Synopsis

In this report, we have treated with some preservatives on keeping quality of fish and fish products.

The effectiveness of Dehydroacyl Acetic Acid (3-iso valeryl-4-hydroxy-6-iso butyl-pyrone (2)) was not remarkable, but Chloramphenicol (Chloromycetin) was shown considerably. The results indicate that the storage life of the fish was prolonged about two times over that of the control, but in the case of boiled fish and fish-cake (KAMABOKO), it was small.

食品防腐剤の効果に関する研究，特に鮮魚については既に極めて多くの研究報告がなされ，最近では防腐の目的でオーレオマイシンの如き抗生物質を使用する試み[1]も行われている。たまたま著者等は新潟大学農学部で新に合成された Dehydroacyl Acetic Acid の誘導体である[2] 3-iso valeryl-4-hydroxy-6-iso butyl-pyrone の鮮魚及び水産加工品に対する防腐効果の試験を依頼されたので，同時に抗生物質である Chlorotetracycline（オーレオマイシン），Chloramphenicol（クロロマイセチン）等の効果をも比較する機会を得たのでその結果の概要を報告する。尚この研究に対し研究費の一部に御援助を頂いた新潟大学農学部玉利勤治郎教授，一部試薬の提供を得た三共株式会社新潟出張所ならびに実験の一部を担当された宮沢玲子嬢に厚く感謝の意を表する。

実 験 方 法

1. 使用した防腐剤

(1) 3-iso valeryl-4-hydroxy-6-iso butyl-pyrone (2)

Dehydroacyl Acetic Acid の誘導体で，以下 DHA—T と記す。50%エチールアルコールに溶解させたもので水に溶解する。

(2) デハイドロ酢酸ソーダ

DHA—Na（台糖株式会社製）を使用。

(3) 5-nitro-2-furfuryl acryl

Zフラン（上野製薬製）を使用。

(4) Chlorotetracycline

魚類処理用オーレオマイシン末（武田薬品製）を適当に稀釈して使用。

(5) Chlorampthenicol

筋注用クロロマイセチン末（三共製薬製）を適当に稀釈して使用。

2. 効果の認定

外観，臭気等の肉眼観察の外，pH値はベツクマンの硝子電極により，アムモニヤ態窒素量はConwayの微量拡散法により，揮発酸は A.O.A.C の改良法[3]により測定し，これらの綜合によつて判断した。

3. 供試魚種及び処理方法

第1回　防腐剤の濃度の影響について

市場に陸揚げされた漁獲後10時間（この間水氷処理）内外の新鮮な大アジを使用した。3枚に身卸しした後，各肉片を種々の濃度の防腐液に室温（23°C）で60分間浸漬した後取揚げ，大型シヤーレーに入れて20°C の恒温器に放置し観察した。

第2回　浸漬時間の影響

漁獲後10時間以内の新鮮なスルメイカの胴肉部のみを使用した。イカ肉の pH 値は6.20，筋肉中のアムモニヤ態窒素量は 12.9mg% で比較的新鮮なものであつた。対照は3.5% の食塩溶液に30分間浸漬し，オーレオマイシン，クロロマイセチンは各 20p.pm を含む3.5% 食塩液に30分間浸漬し，D.H.A—T は 100p.pm を含む3.5% 食塩液に所定時間浸漬した後肉片を取揚げ，大型シヤーレーに入れて冷蔵庫（0°C～4°C）に保管した。浸漬保存の場合は 25cc の前記各溶液中にイカ胴肉を浸漬し，そのまま同じ冷蔵庫に放置し随時取出して調査した。

第3回　各種防腐剤の効力比較

市場より購入した小アジ（巾着網で漁獲され，漁獲後水氷で処理された12時間以内のもの）で鮮度は極めて良好であつた。このものを次の各種防腐液中に室温（23°C）で60分間浸漬し，後これを取揚げて大型シヤーレーに入れ，30°C の恒温器及び 0°C～5°C の冷蔵庫内に放置して実験に供した。

1. 対　　照	3.5%食塩液
2. オーレオマイシン液	20ppm を含む3.5% 食塩液
3. クロロマイセチン液	〃
4. Z フラン液	〃
5. DHA—Na 液	1,000ppm を含む3.5% 食塩液
6. DHA—T液	100ppm を含む3.5% 食塩液

第4回　煮干イワシに対する効果

煮干イワシ製造の際雨天の場合には乾燥することが出来ず，往々にして製品を腐敗させることが多いので，この実験を行つた。原料魚は巾着網で漁獲された中羽イワシ（体長 10cm 内外）で，防腐液に30分間浸漬後新らしい同じ防腐液で20分間煮熟（90°C～95°C）し，網にのせて水切りし，1夜放置してから共栓壜中に密封し，室温（20°C 前後）に放置した。貯蔵開始時のイワシ肉の水分量は71.5%，アムモニヤ態窒素量は 15.4mg%，トリメチールアミン窒素量は 0.62mg% であつた。尚分析はイワシ2尾の精肉を一緒にして行つた

第5回　煉製品に使用した場合

市販カマボコと同じ原料摺肉（スケソータラ肉に澱粉14%，砂糖その他の調味料を混入したもの）500匁に各防腐剤を溶解させた水溶液 100cc（クロロマイセチンの場合は10万分の5.3，DHA—T の場合は1万分の5.3の濃度で製品中に含有する形となる）を添加し，10分間擂潰後板付けし，常法により50分間蒸煮した。これをそのまま 25°C の恒温器及び冷蔵庫（0°C～8°C）内に保管し調査した。

結果と考察

第1回　防腐剤の濃度の影響について

実験結果は第1表に示す.

第1表　防腐液の濃度の影響

経過時間	15時間			21時間			27時間		
検査項目 / 処理方法	筋肉のpH値	筋肉中のアンモニヤ態窒素量 mg%	肉眼観察	筋肉のpH値	筋肉中のアンモニヤ態窒素量 mg%	肉眼観察	筋肉のpH値	筋肉中のアンモニヤ態窒素量 mg%	肉眼観察
対照	6.97	38.8	腐敗臭強し ※卄	7.30	109.3	軟化，完全に腐敗す卅			
3.5% 食塩液	6.67	51.1	同様 卄	7.13	95.1	同様 卅			
DHA—T食塩液濃度20ppm	6.92	62.3	同様 卄	7.50	95.3	同様 卅			
DHA—T食塩液濃度50ppm	6.60	41.3	腐敗臭を感ずるが対照よりは良好 ±	7.35	87.2	同様 卅			
DHA—T食塩液濃度100ppm	6.40	28.1	僅に腐敗臭を感ずる ±	7.30	88.1	同様 卅			
DHA—T食塩液濃度200ppm	6.25	27.9	同様 ±	7.08	82.5	同様 卅			
クロロマイチン食塩液 濃度20ppm	6.25	13.3	極めて新鮮で殆んど変化なし —	6.52	15.8	皮膚に光沢があり未だ良好である ±	6.65	15.8	僅に腐敗を感ずる程度 ±

備考　※腐敗の程度　—極めて新鮮
±初期腐敗の程度
＋腐敗
卄腐敗進行
卅完全に腐敗したもの

即ち D.H.A—T 液の場合には濃度の高い程防腐の効果が見らるれが，僅に 100ppm 濃度以上の場合に実用的に価値ある効果が認められた程度で著るしい効果は期待されない。また 100ppm と 200ppm との間にも顕著な差異は見られなかつた。しかしクロロマイセチンの 20ppm 液浸漬の場合には極めて顕著な効果が見られている。

第2回　浸漬時間の影響

結果は第2表及び第3表に示す。

即ち対照として食塩水に 30 分間浸漬したものと DHA—T 液に 10 分間浸漬したものは全く同様に腐敗が進行して，0°C～4°C の低温でも 7 日後には完全に腐敗の状態を示している。次にオーレオマイシンと DHA—T 液に 30 分間浸漬したものは共に 5 日後に僅に腐敗が進行しておるのが見られるが，オーレオマイシンの方はその後も腐敗の進行が遅く，7 日後においてもまだ食用が可能であるのに対して，DHA—T 浸漬のものはそのまま腐敗が進行して既に食用に耐え難くなつている。DHA—T 液に 60 分間浸漬したものも 5 日までは完全に腐敗の進行を防いであるようであるが，7 日後には急速に腐敗の進行が認めら

第2表 浸漬時間の影響 貯蔵温度 0°C～4°C

経過日数	3日			5日			7日		
調査項目 / 処理方法	筋肉のpH値	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉のpH値	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉のpH値	筋肉中のアンモニヤ態窒素量	肉眼観察
		mg%			mg%				
3.5% 食塩液 30分浸漬	6.42	17.1	色彩鮮度共に良好 −	6.57	35.0	色彩僅かに不良，微臭がある＋	7.28	119.0	腐敗進み悪臭甚し ＋＋
クロロマイセチン食塩液 30分浸漬	6.47	12.0	色彩最も良好 −	6.59	17.6	3日目と変化なし −	6.48	16.8	色彩僅に不良となる鮮度は良好 −
オーレオマイシン食塩液 30分浸漬	6.53	14.7	色彩鮮度共に良好 −	6.58	21.0	色彩僅かに不良，初期腐敗の傾向 ±	6.60	20.3	5日目と同様 ±
DHA—T 食塩液 10分浸漬	6.40	15.4	同上 −	6.61	34.4	色彩僅かに不良，微臭がある＋	7.15	103.6	腐敗進み悪臭甚し ＋＋
DHA—T 食塩液 30分浸漬	6.48	17.6	同上 −	6.55	27.2	色彩僅かに不良，初期腐敗の傾向 ±	6.95	86.8	可成り腐敗進む悪臭 ＋
DHA—T 食塩液 60分浸漬	6.28	11.2	同上 −	6.32	17.9	3日目と変化なし −	6.88	68.0	急に腐敗進む悪臭 ＋

第3表 浸漬したまま放置した場合の変化 貯蔵温度 0°C～4°C

経過日数	3日			5日			7日		
調査項目 / 処理方法	筋肉のpH値	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉のpH値	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉のpH値	筋肉中のアンモニヤ態窒素量	肉眼観察
		mg%							
3.5% 食塩液 浸漬	6.27	4.8	肉質は膨潤しておるが鮮度は良好 − 斑点は黄褐色	6.69	22.7	微悪臭，液は薄桃色 ＋	7.52	37.8	悪臭食用に耐えず ＋＋
クロロマイセチン食塩液 浸漬 (20ppm)	6.02	5.3	同様 − 斑点は黒色で小さい	6.01	3.4	殆んど変化なし −	6.06	4.8	芳香を呈し著るしい変化は見られない −
オーレオマイシン食塩液 浸漬 (20ppm)	6.09	3.5	同様 −	6.07	3.8	殆んど変化なし −	6.10	3.4	同様 −
DHA—T 食塩液 浸漬 (100ppm)	6.22	3.9	同様 斑点は黄褐色を呈す	6.32	11.8	液は薄桃色著るしい変化なし ±	6.69	31.4	微悪臭を呈し不快感を与える ＋

第 4 表—1　各種防腐剤の効果　　貯蔵温度30°Cの場合

経過時間	5 時 間		11 時 間		18 時 間		23 時 間	
調査項目 / 防腐剤の種類	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察
	mg%		gm%		mg%		mg%	
対照（3.5%食塩水）	18.60	—	79.2	##	187.9	##	—	
DHA—Na	16.8	—	40.0	+	159.3	##		
DHA—T	13.2	—	45.4	##	173.9	##		
Zフラン	13.4	—	70.8	##	163.4	##		
オーレオマイシン	16.5		18.2	—	55.2	##	166.9	##
クロロマイセチン	18.8	—	17.6	—	—	##	143.1	##

第 4 表—2　各　種　防　腐　剤　の　効　果　　貯蔵温度　0°Cの場合

経過時間	3 日		5 日		7 日		8 日		9 日		10 日		12 日	
調査項目 / 防腐剤の種類	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	肉眼観察
	mg%		mg%		mg%		mg%		mg%		mg%		mg%	
対　照	19.6	—	25.5	±	58.6	##	71.1	##	94.0	##	118.2	##	—	—
DHA—Na	18.5	—	24.6	±	40.2	+	56.3	##	73.4	##	101.6	##	—	—
DHA—T	22.1	—	30.6	+	64.1	##	86.7	##	108.4	##	142.0	##	—	—
Zフラン	17.2	—	22.12	—	37.5	+	53.5	##	64.7	##	86.2	##	155.7	##
オーレオマイシン	15.6	—	25.8	—	25.2	±	32.1	+	37.2	+	47.0	+	57.1	##
クロロマイセチン	17.9	—	17.6	—	20.7	—	16.0	-	20.4	—	22.4	±	55.2	+

第5表　煮干イワシに対する効果

経過日数	2日後			4日後			5日後			7日後		
調査項目 / 防腐剤	筋肉中のアンモニヤ態窒素量	筋肉中のトリメチールアミン窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	筋肉中のトリメチールアミン窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	筋肉中のトリメチールアミン窒素量	肉眼観察	筋肉中のアンモニヤ態窒素量	筋肉中のトリメチールアミン窒素量	肉眼観察
	mg%	mg%		mg%	mg%		mg%	mg%		mg%		
対照	16.1	0.88	−	31.5	1.35	±	81.6	1.38	+	164.2	1.84	++
DHA−T	13.4	0.84	−	23.1	1.04	−	39.9	1.12	±	71.8	1.20	+
クロロマイセチン	11.6	0.92	−	31.5	0.68	+	48.3	1.10	+	128.1	1.28	++

第6表−1　煉製品に対する効果　　室温（25°C）放置の場合

経過時間	1日			2日			3日			4日		
調査項目 / 防腐剤の種類	アンモニヤ態窒素量	揮発酸量	肉眼観察	アンモニヤ態窒素量	揮発酸量	肉眼観察	アンモニヤ態窒素量	揮発酸量	肉眼観察	アンモニヤ態窒素量	揮発酸量	肉眼観察
	mg%	mg%		mg%	mg%		mg%	mg%		mg%	mg%	
対照	4.9	20.0	ネト酸敗臭なし食用可能	6.0	33.1	表面にネト，酸臭を呈し，食用不能	6.3	63.5	酸敗悪臭強し	—	—	酸敗悪臭甚し
DHA−T	6.3	26.8	同上	9.8	35.6	ネト僅かに発生，酸臭はない，洗えば食用は可能	9.1	38.3	前日と同様	5.2	65.9	酸臭なし，洗いば食用可能
クロロマイセチン	9.1	6.8	同上	6.3	9.6	ネト酸臭なし，食用可能	6.0	12.9	ネト酸臭なし，青カビ発生	—	—	全面にカビ発生食用不能

第6表—2　煉製品に対する効果　　低温度（0°C～8°C）に放置した場合

経過時間	4日			11日			16日			17日		
調査項目 / 防腐剤の種類	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察
対照	6.6	18.0	ネト酸敗臭なし，食用可能	5.4	24.3	変化なし	3.9	25.7	全面にネト発生，内部は食用可能	5.5	45.7	全面にネト発生黄色となる，食用不能
DHA—T	4.3	36.9	同上	5.4	35.6	同上	3.2	24.9	表面に僅にネト発生，洗えば食用可	5.2	34.7	表面ネト甚し，内部は食用不能
クロロマイセチン	8.3	12.0	同上	9.6	9.9	同上	7.4	11.0	ネト，悪臭なし，食用可能	6.0	10.7	ネト発生するも洗えば食用可能

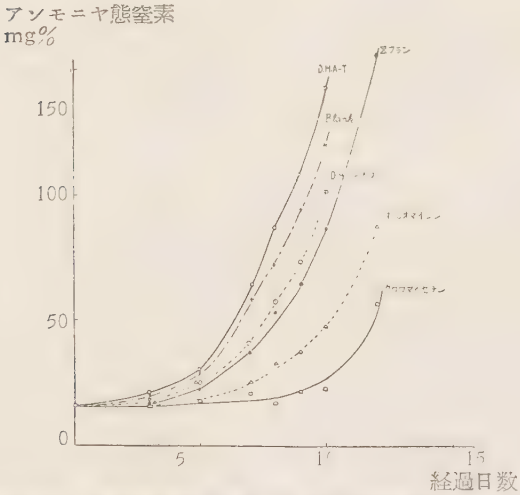
経過時間	18日			20日			23日		
調査項目 / 防腐剤の種類	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察	アンモニヤ態窒素量 mg%	揮発酸量 mg%	肉眼観察
対照	3.5	56.6	ネト，黄色食用不能	7.7	86.2	腐敗甚し	6.3	97.1	腐敗甚し
DHA—T	4.9	43.5	ネト，黄色気味内部良好	3.5	54.7	ネト，黄変するも内部は良好である	6.0	104.2	同上
クロロマイセチン	3.5	11.8	一部ネト内部良好	2.4	14.0	青カビ発生内部は食用可能	4.9	14.8	青カビ紅色カビ発生かなり腐敗進行す

れ，DHA—T 液は或る程度腐敗細菌の発育を抑制するが，或る限度以上に細菌が発育すると急速にその効果を失うもののように見える。一方クロロマイセチンの 20p.p.m 液に 30 分間浸漬したものは極めて良好な状態で 7 日後でも漁獲時と大差のない新鮮さをした。

次に完全にイカ肉を液中に浸漬した（即ち水晒し式）場合の結果は第 3 表に示すようで，この場合にも矢張り他の多くの魚肉の水漬の場合と同様に[4] 筋肉の pH 値の上昇が遅い。この場合には筋肉中のアムモニヤ窒素が浸漬液中に溶出しておることも考えられるが，特にアムモニヤの発生量が少い。しかしこの場合でも矢張りクロロマイセチン液に浸漬したものが最も良好であり，DHA—T 液は殆んど効果を示しておらない。

第 3 回　各種防腐剤の効力比較

オーレオマイシン，クロロマイセチン，Z—フラン，DHA—Na 及び DHA—T の各溶液に 60 分間浸漬したものと，対照として食塩水に浸漬したものを 30°C の室温に放置して比較した結果は第 4 表に示すようで，オーレオマイシン，クロロマイセチンはかなり有効で，18 時間後に初めて腐敗している。しかし Z—フランや D.H.A の誘導体はその効果が割合に小さく，殆んど対照と変りなく腐敗が進行し，11 時間後には既に初期腐敗の状態を示している。



第 1 図　各種防腐剤で処理した場合の筋肉中のアンモニヤ態窒素量の増加（原料アジ 0°c～5°c で貯蔵）

次に 0°C～5°C の比較的低温度に放置した場合の結果は第 4 表の 2 及び第 1 図に示すようで，D.H.A—T 液は殆んど対照と変りがなく腐敗が進行し，ついで DHA—Na，Z—フランの順であるが，その効果は極めて少なく，対照と著るしい差を示しておらない。オレオマイシンはかなり効果的で，1 週間後に初めて初期腐敗の模様が見られる。クロロマイセチンはこの場合も最も良好で，10 日後においても初期腐敗に達せず，12 日後に初めて腐敗している。

第 4 回　煮干イワシに対する効果

煮熟したイワシ（釜揚げイワシ）に対する試験結果は第 5 表に示すようである。

即ちこの場合は前 3 回の実験と異つてクロロマイセチンの場合には殆んど効果が認められず，却つて D.H.A—T 液の効果がかなり認められた。この原因としては加熱操作により試薬が変性し，その効果を失うのではないかとも考えられるが，クロロマイセチンは熱に対してはかなり安定で，蒸溜水中では 4～5 時間の煮沸に耐えるともいわれておるので，試薬に対する安定性の為ではなく，加熱によつて発育する微生物の様相が異るためであると考えた方がよいようである。

第 5 回　練製品に使用した場合

D.H.A—T 及びクロロマイセチンをカマボコ肉中に擂込んだ場合の効果は第 6 表に示すようで，DHA—T は余り著るしい効果は期待出来なかつた。クロロマイセチン混入の場合はカビやネトの発生防止には効果が見られないが，揮発酸の生成が極めて少いことからも，内部の酸生成，変敗の防止に対しては極めて効果的であり，しかしこの場合クロロマイセチンは一種の苦味を呈するので，現状では練製品に混入することは出来ない。

第 6 表で貯蔵中アムモニヤ態窒素の増加が殆んど認められないのは，既に清水[5] が報告しておるように試

験品が含糖蒲鉾であるので，酸生成変敗を起しておることを示している。また D.H A—T を混入した場合には最初から揮発酸の量が極めて多いが，これは D.H.A—T を溶解したアルコールが混入した為であろうと思われる。

以上数回の実験結果から従来鮮魚の保蔵上極めて効果的であるとされたオーレオマイシンに比較して，クロロマイセチンは更に優秀な防腐効果を示したが，しかし煮干イワシとか煉製品のような加熱食品の防腐に対してはその効果が小さいことが明らかとされた。このことはクロロマイセチンが熱に対して不安定であると云うことではなくて，煮干や蒲鉾のような加熱食品の場合には鮮魚の場合と異つて，加熱によつて多くの水中細菌が死滅し，また水分量も少いので多くの場合カビやネトの耐乾微生物による変質が多く，このような微生物に対してはその発育抑制の効果が殆んどないか，或は極めて微弱な為ではないかと思われる。一方 DHA—T は Staphylococuus aureus や Bac. Subtilis，酒火落菌等に対してかなり有効であるとの報告[2]があるが，D.H.A の Na 塩等と同様にカビや酵母等の微生物に対しては効果的であるが，他の一般の細菌に対してはその効果が小さく特にこのような鮮魚及び水産加工品の腐敗変質に及ぼす微生物の種類は極めて多いので，鮮魚に対してはその効果が予期以上に小さかつたのではないかと思われる。しかし1～2の実験でその防腐剤が有効であるか無効であるかを断定することは出来ないし，特にこの実験では D.H.A—T は 200ppm 以上の濃度については実験を行つておらず，他の D.H.A—Na 塩等では少く共 0.1% 或はそれ以上の濃度でないと有効でない[6]とも云われておるので，更に高濃度の場合について実験を継続する予定である。

概　　要

鮮魚（イカ，アヂ）及び煮干イワシ，煉製品等の防腐を目的で 3-iso valeryl-4-hydroxy-6-iso butyl（D.H.A—T と記す）の効果を他のクロロマイセチン，オーレオマイシン等と比較した。その結果鮮魚に対してはクロロマイセチンの効果が最も良好で，単に 20p.p.m 液に 30 分内外浸漬することによつて，その保蔵期間を従来の 2 倍以上延長することが出来た。しかし加熱食品である煮干イワシ，煉製品等に対してはその効果は極めて小さかつた。一方 D.H.A—T は 100p.p.m 程度の濃度では鮮魚に対しては殆んどその効果は認められなかつたが，煮干イワシの煮熟に使用すれば幾分その効果が期待された。

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昭和32年8月20日 印刷
昭和32年8月25日 発行

発行所 日本海区水産研究所
新潟市万代島

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